Section 6

SLOPE ROCKFISH

by
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Executive Summary

Pacific ocean perch
For Pacific ocean perch, we used the generic rockfish model template as the primary assessment tool. This template was developed in a modeling workshop held at the Auke Bay Laboratory in February 2001. The model was constructed with AD Model Builder software. The template is a simple age-structured model with allowance for size composition data that is adaptable to several rockfish species. The data sets used included total catch biomass for the years 1961-2002, size compositions from the fishery for 1963-78 and 1990-99, survey age compositions for 1984, 87, 90, 93, 96 and 99, fishery age composition for 2000 and 2001, and survey biomass estimates for 1984, 87, 90, 93, 96, 99, and 2001. The only new data included in the model were the 2002 catch and age composition from the 2001 fishery. Four alternate model configurations were evaluated. ABCs from these alternative models ranged fromed 9,980 mt - 17,300 mt. The base model which had all likelihood emphasis factors set at 1 gave an ABC of 13,660. We recommend that the ABC from this base model be used for the 2003 fishery. This ABC is similar to last year's ABC of 13,190. The corresponding reference values for Pacific ocean perch are summarized in the following:

$B_{40\%}$ (mt)	104,820
B_{2003} (mt)	112,270
$F_{40\%}$	0.050
F_{ABC} (maximum allowable)	0.050
ABC (mt; maximum allowable)	13,660

Also included in this years report (Appendix 6-1) is a preliminary evaluation of model uncertainties. The focus of this analysis is on assumptions regarding natural mortality M and survey catchability *q*. This analysis indicates the need for further research into identifying and quantifying the sources of uncertainty in the model. Most changes to the way parameters are estimated and weighted resulted in lower estimates for ABC, with the main exception being a higher weight on survey biomass. This does not imply that the current model is overestimating ABC, just that caution is necessary while uncertainties are quantified.

Northern rockfish
For northern rockfish, the age-structured model from last years SAFE was used. The model was updated to include catch from 2001, preliminary catch for 2002, fishery age compositions from 2000 and 2001, and fishery length compositions from 1999, 2000, and 2001. Based on this model the recommended ABC is 5,540 mt. The corresponding reference values for northern rockfish are summarized in the following:

$B_{40\%}$ (mt)	25,270
B_{2003} (mt)	42,740
$F_{40\%}$	0.056
F_{ABC} (maximum allowable)	0.056
ABC (mt, maximum allowable)	5,540

This ABC is the maximum allowable ABC under tier 3. In spite of two recent high survey biomass estimates, the uncertainty of the recent survey biomass estimates and the declining stock trend indicated by the age structured model suggest that precaution is warranted for management of this stock.

Shortraker, rougheye, and other slope rockfish
As in the past, exploitable biomass for shortraker and rougheye rockfish and other slope rockfish was estimated by the unweighted average of the last three trawl survey results, excluding the biomass in the 1-100 m depth stratum. The 1-100 m depth stratum was removed from the estimate because most slope rockfish in this stratum are small juvenile fish younger than the age of recruitment, and thus are not considered exploitable. This results in an exploitable biomass of 66,830 mt for shortraker/ rougheye rockfish and 107,962 mt for other slope rockfish. Applying a combination of F=M and F=0.75M rates results in ABC's of 1,610 mt for shortraker/rougheye rockfish and 5,040 mt for other slope rockfish. Development of an age-structured model for rougheye rockfish was initiated using the rockfish template. However, assessing rougheye rockfish with an age-structured model is still in a very preliminary stage.

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6.1 INTRODUCTION

At least 30 rockfish species of the genus *Sebastes* inhabit waters of the Gulf of Alaska (Eschmeyer et al. 1983), and many are commercially valuable. Since 1988 in this region, the North Pacific Fishery Management Council (NPFMC) has divided these species into three management assemblages based on their habitat and distribution: demersal shelf rockfish, pelagic shelf rockfish, and slope rockfish.

Slope rockfish are defined as those species of *Sebastes* that, as adults, inhabit waters of the outer continental shelf and continental slope of the Gulf of Alaska, generally in depths greater than 150-200 m. In contrast, shelf rockfish inhabit shallower, more inshore waters of the shelf. Based on these criteria, 21 species of rockfish are classified into the slope rockfish assemblage (Table 6-1). The assemblage is dominated by one species, Pacific ocean perch (*Sebastes alutus*), which has historically been the most abundant rockfish in this region and has provided most of the past commercial catch.

Slope rockfish are viviparous, with internal fertilization and release of live young. For most species insemination appears to occur in the fall, and release of larvae occurs during spring and early summer. Identification of the larvae of many species of slope rockfish is not yet possible (Gharrett et al. 2000). Consequently there is considerable uncertainty about the early life history of many species. Slope rockfish are very slow growing and long lived with natural mortality rates usually less than 0.10. Maximum ages differ by species and may be as great as 140 yrs as is the case for rougheye rockfish (*S. aleutianus*).

Few studies have been conducted on the stock structure of slope rockfish. For some species, differences among areas in age composition, growth, fecundity, and prevalence of parasites suggest separate populations at the adult stage (Gunderson 1972; Leaman and Kabata 1987; Moles et al. 1998). Based on allozyme variation, Seeb and Gunderson (1988) concluded that Pacific ocean perch are genetically quite similar throughout their range, and genetic exchange may be the result of dispersion at early life stages. In contrast, preliminary analysis using mitochondrial DNA techniques suggest that genetically distinct populations of Pacific ocean perch exist (A. J. Gharrett pers. commun., University of Alaska Fairbanks, October 2000). Hawkins et al. (1997) and Gharrett and Gray (1998) concluded that that two genetically distinct populations of rougheye rockfish exist with partially overlapping geographic ranges. Currently, genetic studies are underway that should clarify the genetic stock structure of some species of slope rockfish.

In 1991, the NPFMC divided the slope assemblage in the Gulf of Alaska into three management subgroups: Pacific ocean perch, shortraker/rougheye rockfish, and all other species of slope rockfish. In 1993, a fourth management subgroup, northern rockfish, was also created. These subgroups were established to protect Pacific ocean perch and shortraker, rougheye, and northern rockfish (the four most sought-after commercial species in the assemblage) from possible overfishing. Each subgroup is now assigned an individual ABC (acceptable biological catch) and TAC (total allowable catch), whereas prior to 1991, an ABC and TAC was assigned to the entire assemblage. Each subgroup ABC and TAC is apportioned to the three management areas of the Gulf of Alaska (Western, Central, and Eastern) based on distribution of exploitable biomass.

Amendment 58, which took effect in 1998, prohibited trawling in the Eastern area east of 140 degrees W. longitude. Since most slope rockfish, especially Pacific ocean perch, are caught exclusively with trawl gear, this amendment could have concentrated fishing effort for slope rockfish in the Eastern area in the relatively small area between 140 degrees and 147 degrees W. longitude that remained open to trawling. To ensure that such a geographic over-concentration of harvest would not occur, since 1999 the NPFMC has divided the Eastern area into two smaller management areas: West Yakutat (area between 147 and 140 degrees W. longitude) and East Yakutat/Southeast Outside (area east of 140 degrees W. longitude). Separate ABC's and TAC's are now assigned to each of these smaller areas for Pacific ocean perch and the "other slope rockfish" management subgroup.

6.2 FISHERY

6.2.1 Historical Background

A Pacific ocean perch trawl fishery by the U.S.S.R. and Japan began in the Gulf of Alaska in the early 1960's (Figure 6-1). This fishery developed rapidly, with massive efforts by the Soviet and Japanese fleets. Catches peaked in 1965, when a total of nearly 350,000 metric tons (mt) was caught. This apparent overfishing resulted in a precipitous decline in catches in the late 1960's. Catches continued to decline in the 1970's, and by 1978 catches were only 8,000 mt.

Detailed catch information for slope rockfish in the years since 1977 is listed in Table 6-2a for the commercial fishery and in Table 6-2b for research cruises. The reader is cautioned that actual catches of slope rockfish in the commercial fishery are only shown for 1988-2002; for previous years, the catches listed are for the Pacific ocean perch complex (a former management grouping consisting of Pacific ocean perch and 4 other rockfish species), Pacific ocean perch alone, or all *Sebastes* rockfish, depending upon the year (see Footnote in Table 6-2). The acceptable biological catches and quotas in Table 6-2 are Gulfwide values, but in actual practice the NPFMC has divided these into separate, annual apportionments for each of the three regulatory areas of the Gulf of Alaska. (As explained in the last paragraph of section 6.1, the Eastern area for Pacific ocean perch and "other slope rockfish" has been subdivided into two areas, so there are now a total of four regulatory areas for these two management groups.)

Foreign fishing dominated the fishery from 1977 to 1984, and catches generally declined during this period. Most of the catch was taken by Japan (Carlson et al. 1986). Catches reached a minimum in 1985, after foreign trawling in the Gulf of Alaska was prohibited.

The domestic fishery first became important in 1985, and expanded each year until 1991. Much of the expansion of the domestic fishery was apparently related to increasing annual quotas; quotas increased from 3,702 mt in 1986 to 20,000 mt in 1989. In the years 1991-95, overall catches of slope rockfish diminished as a result of the more restrictive management policies enacted during this period. The restrictions included: (1) establishment of the management subgroups, which limited harvest of the more desired species; (2) reducing levels of total allowable catch (TAC) to promote rebuilding of Pacific ocean perch stocks; and (3) conservative in-season management practices in which fisheries were sometimes closed even though substantial unharvested TAC remained. These closures were necessary because, given the large fishing power of the rockfish trawl fleet, there was substantial risk of exceeding the TAC if the fishery were to remain open. Since 1996, catches of Pacific ocean perch have increased again, as good recruitment and increasing biomass for this species have resulted in larger TAC's. In the last several years, the TAC's for Pacific ocean perch have been fully taken (or nearly so) in each management area except Southeastern. (The prohibition of trawling in Southeastern during these years has resulted in almost no catch of Pacific ocean perch in this area.) Catches of northern rockfish were much less than their TAC in 2000-2002: in 2000 and 2002, as a conservative measure to ensure the TAC was not exceeded, and in 2001 because the maximum allowable bycatch of Pacific halibut was reached in the central Gulf of Alaska for "deep water trawl species", one of which is northern rockfish.

Historically, bottom trawls have accounted for nearly all the commercial harvest of slope rockfish. In recent years, however, a sizeable percentage of the shortraker/rougheye rockfish catch has been taken by longlines, and a sizable portion of the Pacific ocean perch catch has been taken by pelagic trawls. In the years 1993-2001, longline catches on an annual basis have ranged from 30% to 58% of the total Gulfwide harvest of shortraker/rougheye. In 2002, the proportion of shortraker/rougheye caught by longline was 40.5%. Most of the shortraker/rougheye taken on longlines are caught incidentally in the sablefish and halibut longline fisheries. The percentage of the Pacific ocean perch Gulfwide catch taken in pelagic trawls increased from 2-8% during 1990-95 to 14-20% during 1996-98. In the years 1999-2001, the amount caught in pelagic trawls has remained moderately high, with annual percentages of 17.6, 10.3, and 11.7, respectively.

Before 1996, most of the slope rockfish trawl catch (>90%) was taken by large factory-trawlers that processed the fish at sea. A significant change occurred in 1996, however, when smaller shore-based trawlers began taking a sizeable portion of the catch in the Central area for delivery to processing plants in Kodiak. The following table shows the percent of the total catch of Pacific ocean perch and northern rockfish in the Central area that shore-based trawlers have taken since 1996[1]:

	Percent of catch taken by shore-based trawlers in the Central area						
	1996	1997	1998	1999	2000	2001	2002
Pacific ocean perch	49	28	32	41	52	43	58
Northern rockfish	32	32	53	44	73	57	73

Factory trawlers continued to take nearly all the catch in the Western and Eastern areas.

6.2.2 Species composition

Detailed species composition data for the "other slope rockfish" and shortraker/rougheye subgroups in the 1992-2001 commercial fishery are available from the domestic observer program (Tables 6-3a and 6-3b). One caveat is that these data are based only on trips that had observers on board. Consequently, they may be somewhat biased toward larger vessels, which had more complete observer coverage. For "other slope rockfish", the percentage data in Table 6-3 can be applied to the commercial catches in Table 6-2a to yield the following Gulfwide estimates of catch in mt for each species:

[1] National Marine Fisheries Service, Alaska Region, Fishery Management Section, P.O. Box 21668, Juneau, AK 99802-1688. Data are from weekly production and observer reports through October 5, 2002.

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Northern rockfish	7,770	-	-	-	-	-	-	-	-	-
Sharpchin rockfish	434	1,345	330	342	278	316	319	169	274	162
Redstripe rockfish	261	1,222	207	198	134	291	51	107	51	44
Harlequin rockfish	745	1,864	789	667	403	492	443	438	186	281
Silvergrey rockfish	130	487	219	123	8	34	8	19	19	18
Yellowmouth rockfish	102	498	40	15	6	63	1	2	13	8
Redbanded rockfish	-	-	23	22	30	15	20	21	25	36
Other species	2	16	4	31	23	6	21	32	10	11

These data indicate that for the current subgroup (i.e., excluding northern rockfish), harlequin, sharpchin, redstripe, silvergrey, and yellowmouth rockfish have been the predominant species caught in the commercial fishery. Also, it should be noted that there was a substantial increase in the catch of these five species in 1993, when northern rockfish were removed from the subgroup. Apparently, removing northern rockfish resulted in an expansion in the fishery for the other species. In 1994-1998, however, the estimated catches for all these species decreased considerably, due at least in part to the lower TAC's set for the subgroup in these years. Catches have remained low since 1998 because of the trawl closure that began that year in the eastern Gulf of Alaska. Most of the biomass of "other slope rockfish" species is located in this area, and fishermen have apparently been unsuccessful or not interested in catching these species with non-trawl gear.

For the shortraker/rougheye subgroup, Table 6-3b shows that shortraker rockfish have always predominated in the commercial catch composition, in some years by a substantial margin. This is not surprising, as shortraker rockfish usually have a higher market value than rougheye rockfish.

6.2.3 Bycatch

The only analysis of bycatch in slope rockfish fisheries of the Gulf of Alaska is that of and Ackley and Heifetz (2001). They examined data from the observer program for the years 1993-95. For hauls targeting Pacific ocean perch, the major bycatch species were arrowtooth flounder, shortraker/rougheye rockfish, sablefish, and "other slope rockfish". (This was based only on data for 1995, as there was no directed fishery for Pacific ocean perch in 1993-94.) For hauls targeting on northern rockfish, the principle bycatch species was dusky rockfish, followed by "other slope rockfish". Although regulations called for no directed fishing for shortraker/rougheye rockfish during these years, Ackley and Heifetz (2001) identified some hauls in which these two species were targeted; the major bycatch in these hauls was arrowtooth flounder, sablefish, and shortspine thornyhead.

The bycatch of slope rockfish species in non-rockfish fisheries has not been well documented. As previously mentioned, a substantial portion of the shortraker/rougheye annual catch comes as bycatch in the longline fisheries for Pacific halibut and sablefish. Presumably, some slope rockfish are also taken in flatfish trawl fisheries.

6.2.4 Discards

Gulfwide discard rates[2] (% discarded) for the four slope rockfish management subgroups in the commercial fishery for 1991-2002 are listed as follows:

[2]Source: National Marine Fisheries Service, Alaska Region, Fishery Management Section, P.O. Box 21688, Juneau, AK 99802-1688. Data are from weekly production and observer reports through October 5, 2002.

Year	Pacific ocean perch	Shortraker/ rougheye	Northern rockfish	Other slope rockfish
1991	15.7	42.0	-	20.0
1992	21.5	10.4	-	29.7
1993	79.2	26.8	26.5	48.9
1994	60.3	44.8	17.7	65.6
1995	19.8	30.7	12.7	72.5
1996	17.2	22.2	16.5	75.6
1997	14.3	22.0	27.8	52.1
1998	14.0	27.9	18.3	66.3
1999	13.8	30.6	11.1	68.7
2000	10.7	21.2	8.7	52.8
2001	8.5	29.1	17.5	47.9
2002	7.2	20.8	9.8	58.0

The high discard rates for Pacific ocean perch in 1993 and 1994 can be attributed to its "bycatch only" status for most of this time period. Since then, discard rates for Pacific ocean perch have steadily decreased. Relatively high discard rates are also seen for "other slope rockfish" in 1993-2002, after northern rockfish were no longer in the group. Many of the remaining species in this group, such as harlequin and sharpchin rockfish, are small in size and of lower economic value, and there may be less incentive for fishermen to retain these fish. The above table also indicates that discards of shortraker/rougheye have generally been moderate, whereas discards of northern rockfish have been relatively low over the years.

6.3 DATA

6.3.1 Fishery Data

6.3.1.1 Catch

Detailed catch information for slope rockfish is listed in Table 6-2a.

6.3.1.2 Catch Per Unit Effort (CPUE) in the Japanese Trawl Fishery

The Japanese trawl fishery in the Gulf of Alaska provided detailed catch and effort information on Pacific ocean perch for the years 1964-84. These data indicated a steep decline in stock abundance of Pacific ocean perch from 1965 to 1976, and that stocks remained severely depressed in the years 1977-84 (Carlson et al. 1986). This time series of CPUE data ended in 1984 when Japanese trawl fisheries in the Gulf of Alaska were terminated.

6.3.1.3 Age and Size composition

Observers aboard fishing vessels and at onshore processing facilities have provided data on size and age composition of the commercial catch of slope rockfish. Tables 6-4 and 6-5 summarize the length compositions for Pacific ocean perch and northern rockfish. Figures 6-2 and 6-3 summarize available age compositions for Pacific ocean perch and northern rockfish. The age compositions for northern rockfish indicate the presence of a stronger than average year class between the years 1982 and 1985. The clustering of several larger than average year classes in this period is most likely due to ageing error. A stronger than average year class around the years 1983-1985 is also indicated by the survey age compositions described below. The age compositions for Pacific ocean perch in both the 2000 and 2001 fishery show strong 1988 and 1987 year classes. These year classes were also strong in age compositions from the 1999 trawl survey, which will be discussed below in section 6.3.2.4.1. Previous trawl surveys in 1993 and 1996, however, showed a strong year class for Pacific ocean perch in 1986, instead of 1988 and 1987.

6.3.2 Survey Data

6.3.2.1 Longline Surveys in the Gulf of Alaska

Two longline surveys of the continental slope of the Gulf of Alaska provide data on the relative abundance of slope rockfish in this region: the earlier Japan-U.S. cooperative longline survey, and the ongoing NMFS domestic longline survey. These surveys compute relative population numbers (RPN's) and relative population weights (RPW's) of rockfish on the slope as indices of stock abundance. Rougheye and shortraker rockfish are the primary rockfish species caught. The results for both surveys concerning rockfish, however, should be viewed with some caution, as the analyses do not take into account possible effects of competition for hooks with other species caught on the longline.

The cooperative longline survey was conducted annually during 1979-94, but RPN's for rockfish are only available for the years 1979-87 (Sasaki and Teshima 1988). These data are highly variable and difficult to interpret, but suggest that abundance of rougheye and shortraker rockfish remained stable in the Gulf of Alaska (Clausen and Heifetz 1989). The data also indicate that rougheye and shortraker rockfish are most abundant in the eastern Gulf of Alaska.

The domestic longline survey has been conducted annually since 1988, and RPN's and RPW's have been computed for each year (Table 6-6[3]). For rougheye rockfish, Gulfwide RPN values from this survey have ranged from a low of ~13,000 in 1988 to a high of ~39,000 in 2000; for shortraker rockfish, Gulfwide RPN's have ranged from a low of ~11,000 in 1994 to a high of ~32,000 in 2000. Similarly, lowest and highest Gulfwide RPW values for each species were in these same years. Definite trends in these data over the years are difficult to discern, and the fluctuations in RPN and RPW may reflect random variations in the survey's catch rates, rather than true changes in abundance. It should be noted, however, that the five highest annual Gulfwide RPN's and RPW's for shortraker rockfish were in the years 1997-2001, and relatively high RPN's and RPW's for rougheye rockfish were also seen in these years. In 2002, RPN's and RPW's for both species decreased compared to the 1997-2001period, and this was especially true for shortraker rockfish.

Similar to the cooperative longline survey, the domestic survey results show that abundance of shortraker and rougheye rockfish is highest in the eastern Gulf of Alaska: the Yakutat area consistently has the greatest RPN and RPW values for shortraker rockfish, and the Southeastern area is usually the best for rougheye rockfish.

6.3.2.2 Biomass Estimates from Trawl Surveys

Bottom trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and 1999, and these surveys became biennial in 2001. The surveys provide much information on slope rockfish, including estimates of absolute abundance (biomass), age composition, and growth characteristics. The triennial surveys covered all areas of the Gulf of Alaska out to a depth of 500 m (in some surveys to 1,000 m), but the 2001 survey did not sample the eastern Gulf of Alaska. Other,

[3] C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau AK 99801. Pers. commun. September 2002.

less comprehensive trawl surveys were periodically conducted before 1984 in the Gulf of Alaska, and these have also provided information on age and size composition of slope rockfish. Summaries of biomass estimates from the 2001 trawl survey and comparative estimates from the 1984 to 2001 surveys are provided in Tables 6-7 and 6-8, respectively.

6.3.2.2.1 2001 Biennial Trawl Survey

As noted above, the 2001 trawl survey, in contrast to all the previous triennial surveys, did not cover the eastern Gulf of Alaska. Consequently, biomass estimates for slope rockfish from this survey are only available for the western and central Gulf of Alaska, and these estimates are listed in Table 6-7. Although the eastern Gulf of Alaska was not sampled in 2001, in Table 6-7 we have included substitute estimates of slope rockfish biomass for this region (the Yakutat and Southeastern statistical areas). This allows continuation of the time series of Gulfwide biomass estimates from all the surveys. Two basic approaches were considered to estimate these substitute biomass values for the eastern Gulf of Alaska: a value based on a correspondence with past biomass trends in the western and central Gulf, or a value based only on past eastern Gulf survey estimates. The first approach assumes that there is a proportional relationship between the abundance in each area, that the changes are measured by the trawl survey, and that the abundance in the eastern Gulf can be predicted by the proportional relationship. The second approach makes none of these assumptions, but assumes only that the average of past survey results is a reasonable value to use for 2001. The two approaches were compared for four major species of rockfish (Pacific ocean perch, and shortraker, rougheye, and dusky rockfish) by attempting to predict past eastern Gulf survey results using prior information on all areas for the first approach and using only prior information for the eastern Gulf for the second approach. Neither approach was consistently better than the other. Rather than use a different method for the various species, we recommend using the consistent, simple approach of averaging of the three most recent biomass estimates for the eastern Gulf from the 1993, 1996, and 1999 surveys to compute biomass estimates for this region in 2001. These averages are those listed in Table 6-7 for the eastern Gulf in 2001.

The 2001 trawl survey indicated that Pacific ocean perch was by far the most abundant species in the slope rockfish assemblage, with an estimated Gulfwide biomass of 858,982 mt, or 61.9% of the assemblage total (Table 6-7). Within the area actually sampled in the survey (Shumagin, Chirikof, and Kodiak areas), Pacific ocean perch comprised 63.1% of the slope rockfish biomass. Northern rockfish was the second most abundant species; it comprised 25.6% of the estimated Gulfwide biomass, and 31.5% of the slope rockfish biomass in the area actually sampled in the survey. The 2001 survey did an especially poor job of sampling species in the “other slope rockfish” management subgroup because it did not cover the eastern Gulf of Alaska, where most of the biomass for these species is located.

The biomass estimates for Pacific ocean perch and northern rockfish in 2001 were both greatly influenced by extremely large catches in one or two hauls. Two hauls in the Shumagin area had catches for Pacific ocean perch of ~6 mt each, and the very high biomass there for this species can be mostly attributed to these hauls. Likewise, one haul in the Kodiak area produced the largest catch of northern rockfish (nearly 14 mt) that has ever been encountered in the trawl surveys, and it also resulted in an extremely large biomass estimate. This anomalously high catch explains the high variance and resultant broad confidence interval for Gulfwide biomass of northern rockfish shown in Table 6-7 and Figure 6-4.

6.3.2.2.2 Comparison of Trawl Surveys in 1984, 1987, 1990, 1993, 1996, 1999, and 2001

Gulfwide biomass estimates from each of the trawl surveys are listed in Table 6-8 for all species of slope rockfish. Gulfwide biomass estimates and 95% confidence intervals are also shown graphically in Figure 6-4 for the assemblage’s four most important commercial species. The 1984 survey results should be treated with some caution, as a different survey design was used in the eastern Gulf of Alaska. Also, much of the survey effort in 1984 and 1987 was by Japanese vessels that used a very different net design than what has been the standard used by U.S. vessels throughout the surveys. To deal with this problem, fishing power comparisons of rockfish catches have been done for the various vessels used in the surveys (for a discussion see Heifetz et al. 1994). Results of these comparisons have been incorporated into the biomass estimates listed here, and the estimates are believed to be the best available. Even so, the reader should be aware that use of Japanese vessels in 1984 and 1987 does introduce an element of uncertainty as to the standardization of these two surveys.

The biomass estimates for most species have often been highly variable from survey to survey. One extreme example of this is harlequin rockfish, whose biomass estimate increased from 2,442 mt in 1984 to 63,833 mt in 1987, and then decreased to 17,194 mt in 1990. Such wide fluctuations in biomass do not seem reasonable given the slow growth and low natural mortality rates of all *Sebastes* species; in the particular case of harlequin rockfish, fishing mortality was also considered to be very low over the period of these surveys. Large catches of aggregating species, such as Pacific ocean perch or northern rockfish, in just a few individual hauls can greatly influence biomass estimates and may be a source of much variability. Anomalously large catches have especially affected the biomass estimates for these two species in the 2001 survey (see Section 6.3.2.2.1 above) and the 1999 survey (Heifetz et al. 1999). In past SAFE reports, we have also speculated that a change in availability of rockfish to the survey, caused by unknown behavioral or environmental factors, may explain some of the observed variation in biomass. It seems prudent to repeat this speculation in the present report, while acknowledging that until more is known about rockfish behavior, the actual cause of changes in biomass estimates will remain the subject of conjecture.

Biomass estimates of Pacific ocean perch were relatively low in 1984 to 1990, increased markedly in both 1993 and 1996, and remained relatively high in 1999 and 2001. To examine these changes in more detail, the biomass estimates for Pacific ocean perch in each statistical area, along with Gulfwide 95% confidence intervals, are presented in Table 6-9. The large rise in 1993, which the confidence intervals indicate was statistically significant compared with 1990, was primarily the result of big increases in biomass in the Central and Western Gulf of Alaska. The Kodiak area increased greater than ten-fold, from 15,221 mt in 1990 to 154,013 mt in 1993. The 1996 survey showed continued biomass increases in all areas, especially Kodiak, which more than doubled compared with 1993. In 1999, there was a substantial decline in biomass in all areas except Chirikof, where a single large catch caused a very large estimate. In 2001, the biomass estimates in both the Shumagin and Kodiak areas were the highest of all the surveys. In particular, the biomass in Shumagin was much greater than in previous years; as discussed previously, the increased biomass here can be attributed to very large catches in two hauls. The large biomass in Kodiak in 2001, however, appears to be the result of a number of large or moderately large catches. Although the eastern Gulf of Alaska was not sampled in 2001, the biomass for the western and central areas in 2001 totals 712,077 mt. This value nearly equals the Gulfwide biomass estimates in 1996 and 1999; if the eastern Gulf had been sampled in 2001, the Gulfwide biomass estimate for Pacific ocean perch almost certainly would be higher than in any previous survey.

The trends in the estimated biomass of the other species are quite variable (Table 6-8 and Figure 6-4). Of all the major species, biomass estimates for rougheye rockfish have been the most constant from survey to survey. The estimates for northern rockfish were generally similar for the years 1987-1996, but increased greatly in 1999 and 2001. The biomass for northern rockfish in the latter two surveys would have been much less, except for a single large catch in each survey. Both harlequin and sharpchin rockfish have shown large fluctuations in biomass between the surveys. To a lesser extent, the biomass of shortraker rockfish has also varied considerably. The estimates for shortraker rockfish are especially uncertain, as the major habitat for this species, the 300-500 m depth stratum on the continental slope, is largely untrawlable using the survey's nets. The biomass estimate of silvergrey rockfish consistently increased in each survey from 1984 to 1999, and in the latter year was nine times greater than it was in 1984. As noted previously in Section 6.3.2.2.1, the 2001 survey results are of limited value for determining biomass trends of species in the "other slope rockfish" management subgroup because the survey did not sample the eastern Gulf of Alaska, where most of the abundance of these species is found.

The precision of the biomass estimates for the four most valuable species in the assemblage is shown by the confidence intervals depicted in Figure 6-4. Especially noteworthy are the very large confidence limits for Pacific ocean perch in 1999 and northern rockfish in 1999 and 2001. These confidence limits are much greater than in any of the previous surveys, and indicate that the point biomass estimates associated with these years should be viewed with considerable caution.

6.3.2.3 Survey Size Compositions

Gulfwide population size compositions for Pacific ocean perch, northern rockfish, rougheye rockfish, and shortraker rockfish in the 1990 through 2001 trawl surveys are shown in Figures 6-5 through 6-8. The size composition for Pacific ocean perch in 2001 was bimodal, which differed from the unimodal compositions in 1993, 1996, and 1999. The 2001 survey showed a large number of relatively small fish, ~30 cm fork length, together with another mode at ~38 cm. The 30 cm mode is not apparent in any of the surveys before 2001, and may indicate that some recruitment is occurring. The northern rockfish size compositions are all unimodal, with no indication of recruitment of small fish. The compositions are especially similar in 1996, 1999, and 2001, when mean population lengths were nearly identical at 37-38 cm. The size compositions of rougheye rockfish in 1993, 1996, 1999, and 2001 indicated that a sizeable portion of the population each year was <30 cm in length, which suggests that at least a moderate level of recruitment has been occurring during this period. The 1993, 1996, and 2001 compositions were all skewed to the right, with a mode of about 42-44 cm. All the shortraker rockfish size compositions have been unimodal, with almost no fish caught <40 cm in length. Mean length of shortraker rockfish declined from 61.0 cm in 1990 to 57.3 in 1999. Mean length of shortraker rockfish also apparently declined in 2001, but this may be an artifact of the lack of survey coverage this year in the eastern Gulf of Alaska. Previous Gulfwide trawl surveys (e.g., Martin and Clausen 1995; Martin 1997) have shown shortraker rockfish to be larger in the eastern Gulf of Alaska.

6.3.2.4 Survey Age Compositions

Age composition data are available for Pacific ocean perch and northern rockfish from a number of surveys (Tables 6-10 and 6-11 and Figure 6-9). In the following, we summarize age data for Pacific ocean perch and northern rockfish from the surveys. Recently, NMFS age readers have determined that aging of rougheye rockfish can be moved into a production mode, and available age data for this species are being incorporated into development of an age-structured model (see Section 6.6.3). Experimental aging of shortraker rockfish is in progress, but has not yet moved into a production mode.

6.3.2.4.1 Pacific Ocean Perch

The age compositions from the 1984, 1987, and 1990 surveys showed that although the fish ranged in age up to 78 years, most of the population was relatively young; mean population age was 10.1 years in 1987 and 9.8 in 1990 (Clausen and Heifetz 1989; Heifetz et al. 1993). All three surveys identified a relatively strong 1976 year class and also showed a period of very weak year classes prior to 1976). The weak year classes of the early 1970's may have delayed recovery of Pacific ocean perch populations after they were depleted by the foreign fishery. The 1987 age compositions indicated that in addition to 1976, the 1980 year class was also especially prominent. The 1990 age data, however, showed an unexceptional 1980 year class, and suggested the 1986 year class may have been strong. The 1993 and 1996 surveys verified that the 1986 year class was exceptionally strong. Recruitment of the strong 1986 year class probably accounted for much of the increase in the estimated biomass for Pacific ocean perch in the 1993 and 1996 surveys. The 1999 survey ages, however, did not agree with the 1993 and 1996 ages, as the 1999 data showed the 1987 and 1988 year classes were more abundant than the 1986 year class. Rockfish are difficult to age, especially as they grow older, and perhaps some of the fish in the 1999 samples that were assigned to the 1987 and 1988 cohort were incorrectly aged and actually should have been part of the 1986 year class.

6.3.2.3.2 Northern Rockfish

Age composition data for northern rockfish are available from the 1984, 1987, 1990, 1993, 1996, and 1999 triennial trawl surveys (Figure 6-9). Age results from all six surveys showed that although the maximum age of northern rockfish was much less than that of Pacific ocean perch, the overall population was considerably older. Mean age of northern rockfish in the surveys has consistently increased from 13.1 years in 1984 to 18.6 years in 1999. The age compositions from each survey indicate that recruitment of northern rockfish is highly variable. Several surveys (1984, 1987, 1990, and 1996) show especially strong year classes from the period around 1975-77, although they differ as to which specific years were greatest, perhaps due to aging errors. The 1993, 1996, and 1999 age compositions also indicate the 1983-85 year classes may be stronger than average which is in agreement with recent age compositions obtained from the commercial fishery described above.

6.5 ASSESSMENT PARAMETERS

6.5.1 Natural Mortality, Maximum Age, Age of Recruitment, and Age and Size at 50% Maturity

Estimates of total mortality (Z) and natural mortality (M), maximum age, and recruitment age are shown in Table 6-12. Estimates of Z which were based on catch curves should be considered as upper bounds for M. Estimates of Z for Pacific ocean perch in Archibald et al. (1981) were from populations considered to be lightly exploited and thus are considered reasonable estimates of M. The method of Alverson and Carney (1975) was used to estimate an M of 0.06 for northern rockfish (Heifetz and Clausen 1991). McDermott (1994) used the gonad somatic index method to estimate a range of M for shortraker and rougheye rockfish.

Previously, age and size of maturity information for slope rockfish in the Gulf of Alaska was only available for Pacific ocean perch, and this information was over 20 years old and based on now obsolete aging methods. Recently, new information on female age and size at 50% maturity has become available for Pacific ocean perch, northern rockfish, and sharpchin rockfish from a study in the Gulf of Alaska that is based on the currently accepted break-and-burn method of determining age from otoliths[4]. These new data are summarized below (size is in cm fork length and age is in years):

Species	Management area	Sample size	Size at 50% maturity	Age at 50% maturity
POP	Gulfwide	802	35.7	10
Northern	Central	77	36.1	13
Sharpchin	Eastern	164	26.5	10

6.5.2 Length and Weight at Age

Length-weight coefficients and Von Bertalanffy parameters are shown in Tables 6-13a and 6-13b.

[4]C. Lunsford, National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK 99801. Pers. Commun. July 1997.

6.6 ANALYTIC APPROACH

Pacific ocean perch and northern rockfish are the only species of slope rockfish which are currently assessed using a formal modeling approach. All other species of slope rockfish are assessed based on trawl survey data. Courtney et al. (1999) presented a stock assessment model for northern rockfish using AD Model Builder software. This is the third year that this model will be used for the assessment of northern rockfish.

For the second time, we present results for Pacific ocean perch based on an age-structured model using AD Model Builder software. Previously the stock assessment was based on an age-structured model using stock synthesis. The assessment model used for Pacific ocean perch is a rockfish model template developed in a modeling workshop held in February 2001[5]. The rockfish model template is a modification of the northern rockfish model (Courtney et al., 1999). Four changes were made to the northern rockfish model during construction of the rockfish template. Fishery age compositions and associated likelihood components were added. The spawner recruit relationship was removed from the estimation of beginning biomass (B_0). Survey catchability, q, was computed relative to survey selectivity standardized to a maximum of one (full selectivity), rather than to survey selectivity standardized to an average of one (average selectivity). The penalties for deviations from reasonable fishing mortality parameter estimates were modified. These fishing mortality deviation and regularity penalties are part of the internal model structure and are designed to speed up model convergence. The result is a simple age-structured model with allowance for size composition data that is adaptable to several rockfish species. The results of the rockfish model template fits to Pacific ocean perch and northern rockfish fishery and survey data are summarized below. Enhancements to the rockfish model template and data requirements for use with rougheye rockfish are also summarized.

6.6.1 Pacific ocean perch

6.6.1.1 Model Structure: Application of Rockfish Model Template

In this section we apply the rockfish template to Pacific ocean perch in the Gulf of Alaska. For ease in interpretation and to make the assessment amenable to the template not all data previously used in the stock synthesis model were used. The data sets used include total catch biomass for the years 1961-2002, size compositions from the fishery for 1963-78 and 1990-99, survey age compositions for 1984, 87, 90, 93, 96 and 99, fishery age compositions for 2000, survey biomass estimates for 1984, 87, 90, 93, 96, 99, and 2001. Ageing error and standard errors of survey estimates of abundance were included in the model. New data not previously used include age composition from the 2001 fishery and catch biomass from the 2002 fishery. As in last year's assessment excluded from the model were fishery CPUE for 1964-79, survey age compositions based on surface reading of otoliths (biased ages) for 1963-67, 78, and 79 and based on "break and burn" (imprecise ages) age compositions for 1980-82. These excluded data were generally older and of uncertain reliability. Both survey and fishery selectivity patterns were assumed to be constant over time. Inclusion of fewer data sets and constraints on selectivity enabled easier exploration of model behavior and sensitivity.

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[5]Rockfish Modeling Workshop, NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK. February, 2001.

6.6.1.2 Base model

Except for catch data, our base model was run with all data components given a likelihood weight of 1, and both survey and fishery selectivity patterns constrained to be approximately asymptotic. The catch likelihood was given a weight of 50 in all model runs. As described in Courtney et al. (1999), within a data component likelihood weights were based on sample sizes of (i.e., relative number of hauls) for size and age composition data. Figure 6-10 summarizes the results from the base model. For this base model the fit to survey biomass was poor for the more recent surveys. In addition the fits to some of the survey age compositions was not very good (Figure 6-11). We surmise that this is due to fishery size composition being in discord with some other data components including survey biomass estimates (Figure 6-12). Also note from Figure 6-12 that survey biomass emphasis weights of 1-5 all gave similar values for the overall likelihood and improved the fit to all data components except for fishery size composition. The likelihood component for survey size composition has a large influence on model fits because of the long time series of size composition data. The model uses size composition data by applying a size to age transition matrix.

6.6.1.3 Model Selection

We compare stock assessment results for 4 different model configurations:

Model 1 - base model, all emphasis weights equal 1
Model 2 - survey biomass emphasis weight increased to 5
Model 3 - fishery size composition emphasis weight decreased to 0.5
Model 4 - asymptotic constraint on fishery selectivity relaxed

A comparison of model results is summarized in the following:

	Model			
Likelihood Component	1 Base	2 Survey biomass emphasis = 5	3 Fishery size emphasis = 0.5	4 Domed fishery selectivity
	-ln likelihood			
Catch	0.03	0.03	0.03	0.03
Survey Biomass Index	9.90	8.12	8.86	9.92
Fishery Age Comp	39.16	32.70	27.95	39.65
Survey Age Comp	79.36	78.54	68.01	79.38
Fishery Size Comp	203.05	212.83	239.11	200.93
Total (unwewighted)	331.51	332.22	343.96	329.91
Survey *q*	1.10	1.10	1.56	1.09
$B_{40\%}$ (mt)	104,820	123,800	91,430	105,050
Current female spawning biomass (mt)	112,270	144,860	89,480	112,780
$F_{40\%}$	0.050	0.050	0.050	0.054
F_{ABC}	0.050	0.050	0.047	0.054
ABC (mt)	13,660	17,300	9,980	13,650

Models 1, 2, and 4 have similar total likelihoods thus the overall fit to the data is about the same for these models. Model 3 has a poorer overall fit because the down weighted emphasis on size composition resulted in a significantly poorer fit to size composition data. Current spawning biomass is estimated to be greater than $B_{40\%}$ for all models except for Model 3.

The base model predicted the 1976-77, 1980, 1986 year classes were relatively strong, similar to that predicted in last year's assessment (Figure 6-10). There is considerable uncertainty (i.e. wide confidence limits) for the more recent year classes (1994-2002). Note that the fit to survey biomass is poor for the last three surveys. From a low of about 50,000 mt in 1979 - 1984 spawning biomass has been steadily increasing. Full selection to the survey was estimated to be age 7. Full selection to the fishery is at age 8.

We selected the results from Model 1, the base model, as the basis for our recommendations for ABC and overfishing. While we expect several refinements to the model to be made in the future, this model equally weights all data used in the model, and spawning biomass and ABC are similar to recent assessments. Estimates of the time series of female spawning biomass, biomass (age 6 and greater), catch/biomass, and number of age two recruits are shown in Table 6-14. These estimates are also shown for last year's assessment. A summary of the base model estimates of age composition, fishery and survey selectivity, maturity at age, and weight at age is in Table 6-15.

6.6.1.4 Evaluation of Model Uncertainties

Appendix 6-1 contains a preliminary evaluation of model uncertainties within a Bayesian framework. The focus of this analysis is on assumptions regarding natural mortality M and survey catchability *q*. This analysis indicates the need for further research into identifying and quantifying the sources of uncertainty in the model. Most changes to the way parameters are estimated and weighted result in lower estimates for ABC, with the main exception being a higher weight on survey biomass. This does not imply that the current model is overestimating ABC, just that caution is necessary while uncertainties are quantified. Some of the data are contradictory because different weightings on different data components can result in large changes in model outputs. For future assessments a formal Bayesian framework and decision analysis would be useful to quantify the effects of assumptions about parameters and data.

6.6.2 Northern Rockfish

6.6.2.1 Model Structure

The base model (Model 1) for this year's stock assessment for northern rockfish is the same age-structured model used in last year's stock assessment (last year's northern rockfish Model 2, Heifetz et al. 2001). The model was constructed using AD Model Builder and was described in detail in an earlier SAFE appendix (Courtney et al. 1999). The model is fit to available fishery catch, age, and size compositions and to triennial trawl survey age compositions. Catch is interpolated for missing years (Courtney et al. 1999). Trawl survey biomass estimates are incorporated as indices of abundance by estimating survey catchability (*q)*:

Expected Survey Biomass = *q**(Observed Survey Biomass)

Natural mortality is fixed at an independently estimated value of 0.06 (Table 6-12) and a single selectivity is assumed for the fishery and the survey. Penalty functions are incorporated into the model objective function to constrain recruitment variability, fishing mortality variability, and selectivity at age. Ageing errors are incorporated with the use of age-error and age-length transition matrices. The log parameters are estimated rather than parameters on the original scale for reliability in the estimation process (Kimura 1989, 1990). Additional structure is added to the model by incorporating a stock recruit relationship (Courtney et al. 1999).

Prior distributions are incorporated as penalties in the overall model objective function for recruitment variability, survey catchability, and steepness of the stock recruitment relationship (Courtney et al. 1999).

The initial values and their prior distributions for recruitment variability, survey catchability, and steepness of the stock recruitment relationship area assumed to be similar for northern rockfish and Pacific ocean perch in the Gulf of Alaska.

An alternative model (Model 2) presented this year for northern rockfish is based on a template developed in a modeling workshop held in February 2001[6] (last year's northern rockfish Model 5, Heifetz et al. 2001). The rockfish model template is a modification of the northern rockfish model used in a previous assessment (Courtney et al., 1999). Four changes were made to the northern rockfish model during construction of the rockfish template. Fishery age compositions and associated likelihood components were added. The spawner recruit relationship was removed from the estimation of beginning biomass (B_0). Survey catchability, *q*, was computed relative to survey selectivity standardized to a maximum of one (full selectivity), rather than to survey selectivity standardized to an average of one (average selectivity). The penalties for deviations from reasonable fishing mortality parameter estimates were modified. These fishing mortality deviation and regularity penalties are part of the internal model structure and are designed to speed up model convergence. The result is a simple age-structured model with allowance for size composition data that is adaptable to several rockfish species. The results of the rockfish model template fits to northern rockfish fishery and survey data were compared to the base model.

6.6.2.2 Model Selection

Courtney et al. (1999) found that the 1999 base model fit the age composition and biomass index poorly and did not satisfactorily describe the population structure. An examination of several alternative model likelihood weights revealed that the most likely cause of the poor fit was an apparent inconsistency in the data between the survey age compositions and the fishery length compositions. In particular, the length compositions were composed of a single mode that progressed in size through time (Table 6-5). The model interpreted this mode as a single very large year class, 1976, which dominated the population dynamics of the model. Alternatively, the age composition was composed of several less clearly defined modes which progressed in age through time. An alternative case was obtained by forcing the model to fit the age composition data. In this case, the model estimated several strong year classes and the fishery/survey selectivity curve appeared to be more reasonably defined. The alternative case from 1999 was the preferred model (Courtney et al. 1999) and was implemented for this years assessment with the modifications described below.

New data added for this assessment includes fishery catch from 2001, preliminary catch for 2002, fishery age compositions from 2000 and 2001, and fishery length compositions from 1999, 2000, and 2001.

As done last year, the model fit to survey age composition was improved by increasing the survey age composition likelihood weight from one to ten. Increasing the weight forced the model to fit the survey age data. The actual value chosen for the weighting term was based upon a sensitivity analysis (Figure 10 in Courtney et al. 1999). The sensitivity test suggested that a weighting value of ten was just as effective at fitting the age data as the higher weight of fifty used in the 1999 alternative case model, but that the lower weight had less of an impact on the model's fit to the other data.

As done last year, fishery age composition data and associated model likelihood components were incorporated in the northern rockfish age-structured model. The model fit to fishery age composition was improved by setting the fishery age composition likelihood weight to ten analogously to the survey age composition likelihood weight.

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[6]Rockfish Modeling Workshop, NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK. February, 2001.

As done last year, the maximum age for which selectivity at age is estimated was reduced from age 23+ to age 11. Selectivity at age from ages 12 through 23+ were set equal to that of age 11. The choice of age 11 as the maximum selected age was based upon results of the alternate case model from 1999 (Figure 12 in Courtney et al. 1999). The model showed a local peak in selectivity at age 11 and values ranging above and below the peak after age 11. This behavior suggested an asymptote in selectivity at age 11. A test of model sensitivity to the choice of maximum selected age (ranging from 8 to 14) showed little effect on the population (projected catch in 2001 varied only 6% over the range of values). In this year's assessment, the resulting values estimated for selectivity at age followed a logistic growth pattern with a maximum selectivity at age 11 without assuming a functional relationship between selectivity and age.

In the 1999 model, the number of hauls used to collect fishery length and survey age data were used as weighting terms in the multinomial likelihoods due to fishery size and survey age respectively. The purpose of these weighting terms was to reduce the influence of data collected from a relatively low number of hauls in any given year (for example, 6 in the 1984 age compositions, Table 13B in Courtney et. al. 1999). However, there were generally more hauls observed for fishery length data than for survey age data, and consequently more weight was given to length compositions than to age compositions using this weighting scheme. As done last year, the problem was addressed by scaling the number of hauls for fishery length and age data and for survey age data to a maximum of one hundred. The number one hundred was chosen in order to keep the scale of the sample sizes on the same order of magnitude as the unscaled sample sizes which ranged from 6 to 176 hauls.

Two variations of the northern rockfish model were evaluated for this years assessment, a base model (Model 1) and an alterative model (Model 2). Model 1 is the northern rockfish model from last years assessment with updated data. Model 2 is the rockfish model template developed in 2001[7] except that the weighting terms are tuned to northern rockfish assessment model used last year. Model 2 is the same as Model 1 except that the spawner recruit relationship is removed from the estimation of beginning biomass (B_0); survey catchability, q, is computed relative to a survey selectivity standardized to a maximum of one (full selectivity), rather than to a survey selectivity standardized to an average of one (average selectivity); and the penalties for deviations from reasonable fishing mortality parameter estimates were modified. The fishing mortality deviation and regularity penalties are part of the internal model structure and are designed to speed up model convergence and should not affect model results.

[7]Rockfish Modeling Workshop, NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK. February, 2001.

Model 1	The equivalent to last years northern rockfish assessment model with updated data
Model 2	Rockfish template[7]

A comparison of selected likelihood components and results from the two model runs follow:

	Model	
Selected likelihood components	1*	2
Catch	0.01	0.01
Survey biomass index	6.19	5.99
Fishery age comp	23.28	23.29
Survey age comp	29.21	29.23
Fishery size comp	106.71	106.61
Recruitment deviations	21.30	21.40
Total (unweighted)	186.69	186.53
Selected model results		
Survey q	0.41	0.50
(Spawning biomass 2002)/ (Spawning biomass 2001)	0.97	0.97
(Spawning biomass 2002)/ (Spawning biomass 1977)	1.71	1.81
Average Recruitment (1977, 2002)	18.50	20.67
Total biomass 2002 (mt)	117,497	136,088
(CV)	(37%)	(38%)

*Recommended model for ABC determination

The likelihood components, penalties and selected measures of stock status are similar for the two model runs. As described last year, reformulation of survey catchability in Models 2 affects model results (Heifetz et al. 2001). In particular, the parameter estimate for *q*, the average recruitment, and the ending biomass all increase. This behavior results from a penalty placed on the deviations of estimated *q* from a prior assumption that the value of *q* is equal to one (see description of priors, Courtney et al. (1999)). In the northern rockfish assessment, the penalty is tuned to an estimate of *q* relative to average survey selectivity while in the template model, the penalty is tuned to an estimate of *q* relative to full survey selectivity. Neither the reformulation of fishery mortality regularity and deviation penalties, nor the removal of the spawner recruit relationship from the estimation of beginning biomass (B_0) in Model 2 appear to influence model results (Heifetz et al. 2001).

Model 1, last year's northern rockfish assessment model is recommended for this year's assessment. In spite of two strong recent survey biomass estimates (Figure 6-4), the uncertainty of the recent survey biomass estimates and the declining stock trend indicted by the age structured model suggest that precaution is warranted for management of this stock. Since small changes in estimated survey catchability can have a large influence on model Biomass estimates, more exploratory model runs with the new estimate of survey catchability, *q*, will need to be examined before Model 2 can be recommended for ABC calculations for northern rockfish.

6.6.2.3 <u>Results for Northern Rockfish</u>

Fits of Model 1 to survey age compositions and survey biomass estimates are shown in Figures 6-13 and 6-14. Estimates of the time series of female spawning biomass, total biomass (age 6 and greater), catch/(6+ total biomass), and number of age-two recruits from Model 1 are shown in Table 6-16. Estimates of the trend in recent spawning biomass and estimated number of recruits from Model 1 are shown in Figures 6-15 and 6-16, respectively. A summary of the current Model 1 estimates of age composition, fishery and survey selectivity, maturity at age, and weight at age is in Table 6-17.

The number of age-2 recruits in 2003 was estimated as the average recruitment from the 1977 - 1994 year classes (18,997, Table 6-17). Estimated female spawning biomass in 2003 is 42,743 mt exploitable biomass is 105,263 mt, and age 6+ total biomass is 108,834 mt (Table 6-16).

Recruitment since the 1988 year class has been below average, and the current population is dominated by older fish from three strong year classes (1968-1970, 1975-1977, and 1982-1984, Figures 6-13 and 6-16). The spread in these strong year classes is likely due to ageing error. According to the age structured model, the spawning biomass of these large year classes has already peaked (between 1991 and 1992), and spawning biomass is projected to decrease as these large year classes die off (based upon average recruitment from 1977-1994 year classes, Figure 6-15). Unless another strong year class appears, spawning biomass is projected to fall below $B_{40\%}$ in 2008 and yield is projected to fall below equilibrium yield at $F_{40\%}$ (3,985 mt) by 2010 (Figure 6-15).

The use of an age-structured model has improved our understanding of northern rockfish population dynamics, however there is still considerable uncertainty in the estimates of population abundance. Biomass projections from the age structured model are highly uncertain. The 2002 ending biomass estimated from the age structured model had a coefficient of variation of 38% (based upon the covariance matrix from the AD Model output). This is a minimum estimate of variation that does not take into account the uncertainty of independently estimated parameters such as natural mortality and maturity. For example, estimates of maturity at age are uncertain because they are based on a small sample of fish (n=77) collected in one year and the calculation of $F_{40\%}$ and $B_{40\%}$ depend on estimates of maturity.

The fit to the survey abundance index is poor, and improving the fit changes the resulting biomass estimate. Courtney et al. (1999) tested the model sensitivity to the likelihood weights on the abundance index. Increasing the likelihood weight on the abundance index improved the fit of the abundance index and all the other data except the age data. However, the population representation implied by the age data was chosen as the most reasonable representation of the population structure for this assessment (i.e., the alternative case from Courtney et al. 1999). The uncertainty inherent in this choice was examined in a previous assessment (Heifetz et al. 2000). By increasing the likelihood weight of the survey abundance index from 1(the value used in the current assessment) to 5 (the population representation implied by a stronger fit to survey abundance and the maximum weight from Courtney et al. 1999), the resultant 2000 ending biomass estimate was increased by approximately 50%. This sensitivity to changes in survey biomass weights underscores the uncertainty in the current biomass estimate.

6.6.3 Shortraker and Rougheye Rockfish, and Other Slope Rockfish

As in the past, the average of the exploitable biomasses in the three most recent surveys (1996, 1999, and 2001) is used to determine current exploitable biomass of shortraker and rougheye rockfish and other slope rockfish (Table 6-18). There was no survey of the Eastern Gulf of Alaska in 2001, so the average of the 1993, 1996, and 1999 survey estimates was used in place of a 2001 Eastern Gulf value. These estimates are derived from the Gulf wide biomass estimates listed in Table 6-8, excluding the biomass in the 1-100 m depth stratum. The 1-100 m depth stratum was removed from the estimate because most slope rockfish in this stratum are small juvenile fish younger than the age of recruitment, and thus are not considered exploitable (Clausen and Heifetz 1989). These averages yield the following values of current exploitable biomass: 25,473 mt for shortraker rockfish, 41,356 mt for rougheye rockfish, and 107,962 mt for other slope rockfish.

Development of an age-structured model for rougheye rockfish was initiated last year using the AD Model Builder rockfish template[8]. The rougheye model starts in 1977 and has 40 age bins and 39 length

[8]Rockfish Modeling Workshop, NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK. February, 2001.

bins. Catch data from Soh (1998), survey biomass estimates and size compositions from 6 triennial trawl survey biomass estimates from 1984-1999, 1 year of trawl survey age composition, 5 years of fishery size composition, and 1 year of fishery age composition were input to the template model. A size-age transition matrix was derived from a lognormal fit of Von Bertalanffy growth curve to data from Malecha and Heifetz (2000). A second survey was added to the model so that 13 years of abundance indices and 3 years of size composition data from the longline survey could be incorporated. There are no available estimates of catch prior to 1977, although they were likely taken in significant numbers during the foreign fisheries in the 1960's and early 1970's. Because the template model assumes the population has been unfished at the start of the model, a lack of old fish in the age composition data for these long lived species results in a strongly dome-shaped fishery and survey selectivity curve. The rougheye model was modified to allow for fishing prior to 1977, giving an alternate explanation for the lack of old fish and much less dome-shaped selectivity curves. Assessing rougheye rockfish with an age-structured model is still in a very preliminary stage

6.7 PROJECTIONS AND HARVEST ALTERNATIVES

6.7.1 Pacific Ocean Perch

6.7.1.1 Harvest Alternatives

Several alternate model configurations were evaluated in section 6.6.1. ABCs from these alternative models ranged 9,980 - 17,300 mt. The ABC's are based on an $F_{40\%}$ harvest rate (i.e., Tier 3a), adjusted downward for model 3 because B_{2003} ia less than $B_{40\%}$ (i.e., Tier 3b). We recommend that the ABC from the base model be used for the 2003 fishery. The base model is desirable because all likelihood emphasis factors are set at 1. The ABC is based on an $F_{40\%}$ harvest rate. For last year's ABC recommendation we also used the base model. While we expect several refinements to the model to be made in the future, this ABC is similar to last year's ABC which used the same base model. The corresponding reference values for Pacific ocean perch for alternative models are summarized in the following:

	Model			
	1 * Base	2 Survey biomass emphasis = 5	3 Fishery size emphasis = 0.5	4 Domed fishery selectivity
$B_{40\%}$ (mt)	104,820	123,800	91,430	105,050
B_{2003} (mt)	112,270	144,860	89,480	112,780
$F_{40\%}$	0.050	0.050	0.050	0.054
F_{ABC} (maximum allowable)	0.050	0.050	0.047	0.054
ABC (mt; maximum allowable)	13,660	17,300	9,980	13,650

* Recommended for ABC calculation

Based on model 1, the current spawning biomass in 2003, B_{2003}, is 112,270 mt. $B_{40\%}$ is determined from average recruitment of the 1977-93 year-classes (Figure 6-17). Since B_{2003} is greater than $B_{40\%}$, the computation in tier 3a [i.e., $F_{ABC} \leq F_{40\%}$] is used to determine the maximum value of F_{ABC} resulting in an ABC $\leq$ 13,660 mt. We recommend that the ABC for Pacific ocean perch for 2003 fishery in the Gulf of Alaska be set at 13,660 mt.

6.7.1.2 Projections

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3. This set of projections that encompasses seven harvest scenarios is designed to satisfy the requirements of

Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). Figure 6-18 shows the recent trend and projection of yield and spawning biomass based on average recruitment and a $F_{40\%}$ harvest rate.

For each scenario, the projections begin with the vector of 2002 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2003 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2002. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2003, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2003 recommended in the assessment to the *max* F_{ABC} for 2003. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 1995-1999 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above ½ of its MSY level in 2001 and above its MSY level in 2011 under this scenario, then the stock is not overfished.)

Scenario 7: In 2003 and 2004, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2014, under this scenario, then the stock is not approaching an overfished condition)

A summary of the results of these scenarios for Pacific ocean perch is in Table 6-19. For Pacific ocean perch the stock is not overfished nor is it approaching an overfished condition.

6.7.1.3 Apportionment of ABC

Prior to the 1996 fishery, the apportionment of ABC among areas was determined from distribution of biomass based on the average proportion of exploitable biomass by area in the most recent three triennial trawl surveys. For the 1996 fishery, an alternative method of apportionment was recommended by the Plan Team and accepted by the Council. Recognizing the uncertainty in estimation of biomass yet wanting to adapt to current information, the Plan Team chose to employ a method of weighting prior surveys based on the relative proportion of variability attributed to survey error. Assuming that survey error contributes 2/3 of the total variability in predicting the distribution of biomass (a reasonable assumption), the weight of a prior survey should be 2/3 the weight of the preceding survey. This results in weights of 4:6:9 for the 1993, 99, and 2001 surveys, respectively and apportionments of 19.8% for the Western area, 62.3 % for the Central area, and 17.9% for the Eastern area (Table 6-20). This results in recommended ABC's of 2,700 mt for the Western area, 8,510 mt for the Central area, and 2,450 mt for the Eastern area.

6.7.2 Northern Rockfish

6.7.2.1 Harvest Alternatives

Except for the addition of new data (fishery catch from 2001, preliminary catch for 2002, fishery age compositions from 2000 and 2001, and fishery length compositions from 1999, 2000, and 2001), the model used to recommend northern rockfish ABC this year is the same as the northern rockfish age-structured model from last years SAFE. A detailed report describing the northern rockfish model configuration was presented in an earlier SAFE appendix (Courtney et al. 1999). Based on this year's recommended assessment model (Model 1), the projected current spawning biomass in 2003 B_{2003} is 42,743 mt. $B_{40\%}$, determined from average recruitment of the 1977-94 year-classes is 25,268 mt. Since B_{2003} is greater than $B_{40\%}$, the computation in tier 3a [i.e., $F_{ABC} \leq F_{40\%}$] is used to determine the maximum value of F_{ABC}. As in last year's assessment, we recommend that $F_{40\%}$ be used as the basis for ABC calculations. We recommend that the ABC for northern rockfish for the 2003 fishery in the Gulf of Alaska be set 5,537 mt (Model 1).

The corresponding stock assessment reference values for northern rockfish are summarized in the following:

	Model	
	1*	2
$B_{40\%}$ (mt)	25,268	28,323
B_{2003} (mt)	42,743	49,974
$F_{40\%}$	0.056	0.056
F_{ABC} in 2003 (maximum allowable)	0.056	0.056
ABC in 2003 (mt; maximum allowable)	5,537	6,446

* recommended model for ABC determination

The model recommended for this year's assessment (Model 1) is identical to last year's assessment model (northern rockfish Model 2, Heifetz et al. 2001). Projected spawning biomass (B_{2003}), equilibrium spawning biomass ($B_{40\%}$), and ABC for 2003 from this year's assessment are similar to those from last years assessment. Given the uncertainty in the biomass estimates obtained from the age structured model, the catch history, and the uncertain life history parameters, a model which results in a more conservative ABC, which is similar to that obtained last year, appears to be reasonable. The declining stock trend and the weakness of recent recruitment estimates identified by the age structured model indicates that caution is warranted for management of this stock.

6.7.2.2 Projections

The standard set of projections described for Pacific ocean perch were run for northern rockfish (Model 1). A summary of the results of these scenarios is in Table 6-21. For northern rockfish, projected B_{2003} (42,743 mt) is greater than $B_{35\%}$ (22,109 mt) and by the definitions above, the stock is not overfished. In addition, B_{2005} (37,177 mt) is greater than $B_{35\%}$ and by the definitions above the stock is not approaching an overfished condition.

6.7.2.3 Apportionment of ABC

Using the same method of apportionment as used for Pacific ocean perch (Table 6-20) results in ABC's of 890 mt (16.1%) in the Western area, 4,640 mt (83.8%) in the Central area, and 10 mt (0.1%) in the Eastern area. For management purposes, the small ABC of northern rockfish in the Eastern area is combined with other slope rockfish.

6.7.3 Shortraker and Rougheye Rockfish

In the past, the recommended ABC for shortraker and rougheye rockfish was based on an exploitation rate set equal to natural mortality. Based on recommendations of the Scientific and Statistical Committee (SSC), estimates of M were obtained from Table 6-12 which lists estimates of total mortality Z based on catch curve analyses. The SSC estimated an M of 0.025 for rougheye rockfish based on the mid-point of the range of Z for British Columbia stocks and because there was no estimate of M or Z for shortraker rockfish, the ratio of maximum age of rougheye to shortraker (140/120) multiplied by 0.025 was used to estimate an M of 0.03.

Applying the definitions for ABC and OFL based on Amendment 44 on the Gulf of Alaska FMP places shortraker rockfish in tier 5 where $F_{ABC} \leq 0.75M$. Thus, the recommended F_{ABC} for shortraker rockfish is 0.023 (ie., 0.75 X 0.03). Applying tier 4 to rougheye rockfish (ie., $F_{ABC} \leq F_{40\%}$) results an F_{ABC} =M= 0.025 which is less than $F_{40\%}$=0.032. Applying these F_{ABC}'s to the estimates of exploitable biomass based of 25,473 mt for shortraker rockfish and 41,356 mt for rougheye rockfish results in ABC's of 586 mt for shortraker rockfish and 1,034 mt for rougheye rockfish and a recommended ABC for the subgroup of 1,620 mt.

For species such as shortraker and rougheye rockfish that are not assessed with a age/length- structured model multi-year projections as done in Table 6-19 for Pacific ocean perch are not possible but yields for just the year 2003 can be computed (Table 6-22).

The same method of apportionment as used for Pacific ocean perch is used to apportion the shortraker and rougheye ABC among areas (Table 6-20). This results in ABC's of 220 mt for the Western area, 840 mt for the Central area, and 560 mt for the Eastern area.

6.7.4 Other Slope Rockfish

In the past, the recommended ABC for other slope rockfish was based on a harvest rate set equal to natural mortality M. Estimates of M obtained from Table 6-12 are 0.05 sharpchin rockfish and 0.10 for redstripe rockfish. The estimate of M of 0.04 for silvergrey rockfish is based on the midpoint of the range of Z (0.01-0.07) for British Columbia stocks. For harlequin and redbanded rockfish and minor species, an F=M of 0.06 is based on the average M for northern, sharpchin, redstripe, and silvergrey rockfish. Applying the new definitions for ABC and OFL based on Amendment 44 in the Gulf of Alaska FMP places sharpchin rockfish in tier 4 where $F_{ABC} \leq F_{40\%}$, and the other species of other slope rockfish in tier 5 where $F_{ABC} \leq 0.75M$. Applying $F_{ABC} = M = 0.05$ to the exploitable biomass of sharpchin rockfish and $F_{ABC} = 0.75M$ to the exploitable biomass of the other species results in a recommended combined ABC for other slope of 5,038 mt. Distributing this ABC based on the same method used for Pacific ocean perch results in ABC's of 87 mt in the Western area, 552 mt in the Central area, and 4,399 mt in the Eastern area (Table 6-20).

For species such as other slope rockfish that are not assessed with a age/length- structured model multi-year projections as done in Table 6-19 for Pacific ocean perch are not possible but yields for just the year 2003 can be computed (Table 6-22).

6.7.5 Overfishing Definition

6.7.5.1 Pacific ocean perch and northern rockfish

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., $F_{OFL} = F_{35\%}$=0.060), overfishing is set equal to 16,240 mt for Pacific ocean perch. The overfishing level is apportioned by area for Pacific ocean perch. Using the apportionment in Section 6.7.1, results in overfishing levels by area of 3,220 mt in the Western area, 10,120 mt in the Central area, and 2,900 mt in the Eastern area. Based on the definitions for overfishing in Amendment 44 in tier 3a [i.e., $F_{OFL} = F_{35\%} = 0.066$], overfishing is set equal to 6,565 mt for northern rockfish.

6.7.5.2 Rougheye, shortraker and other slope rockfish

Based on Amendment 44 in the Gulf of Alaska FMP overfishing is defined to occur at the harvest rate set equal to $F_{35\%}$ (in terms of exploitable biomass per recruit) of 0.038 for rougheye rockfish. The F=M rate of 0.03 is used to define the overfishing level for shortraker rockfish because data are not available to determine $F_{30\%}$ for shortraker rockfish. These harvest rates are applied to estimates of current exploitable biomass to yield an overfishing catch limit of 2,340 mt for the shortraker/rougheye subgroup.

Overfishing is defined to occur at the $F_{35\%}$ (in terms of exploitable biomass per recruit) values of 0.064 for sharpchin rockfish. For the other species of other slope rockfish, overfishing is defined to occur at the F=M rate. Applying these F's, results in an overfishing catch limit of 6,390 mt for the other slope rockfish subgroup.

6.7.8 Summary

A summary of biomass levels, exploitation rates and recommended ABCs and OFLs for slope rockfish is in Table 6-23.

6.8 ECOSYSTEM CONSIDERATIONS

In general, a determination of ecosystem considerations for slope rockfish is hampered by the lack of biological and habitat information. A summary of the ecosystem considerations presented in this section is listed in Table 6-24.

6.8.1 Ecosystem Effects on the Stock

Prey availability/abundance trends: similar to many other rockfish species, stock condition of slope rockfish appears to be influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval rockfish may be an important determining factor of year class strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and year class strength; moreover, identification to the species level for field collected larval slope rockfish is difficult. Visual identification is not possible though genetic techniques allow identification to species level for larval slope rockfish (Gharrett et. al 2001). Some juvenile rockfish found in inshore habitat feed on shrimp, amphipods, and other crustaceans, as well as some mollusk and fish (Byerly 2001). Adult slope rockfish such as Pacific ocean perch and northern rockfish feed on euphausiids. Adult rockfish such as shortraker and rougheye are probably opportunistic feeders with more mollusks and fish in their diet. Little if anything is known about abundance trends of likely rockfish prey items. Euphausiids are also a major item in the diet of walleye pollock. Changes in the abundance of walleye pollock could lead to a corollary change in the availability of euphausiids, which would then have an impact on Pacific ocean perch and northern rockfish.

Predator population trends: Rockfish are preyed on by a variety of other fish at all life stages, and to some extent marine mammals during late juvenile and adult stages. Whether the impact of any particular predator is significant or dominant is unknown. Predator effects would likely be more important on larval, post-larval, and small juvenile slope rockfish, but information on these life stages and their predators is nil.

Changes in physical environment: Strong year classes corresponding to the period around 1977 have been reported for many species of groundfish in the Gulf of Alaska, including Pacific ocean perch, northern rockfish, sablefish, and Pacific cod. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including slope rockfish. Pacific ocean perch appeared to have a strong 1986-87 year classes, and these may be other years when environmental conditions were especially favorable for rockfish species. The environmental mechanism for this increased survival remains unknown. Changes in water temperature and currents could have an effect on prey item abundance and success of transition of rockfish from pelagic to demersal stage. Rockfish in the early juvenile stage have been found in floating kelp patches which would be subject to ocean currents. Changes in bottom habitat due to natural or anthropogenic causes could alter survival rates by altering available shelter, prey, or other functions.

6.8.2 Fishery Effects on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: In the Gulf of Alaska, bottom trawl fisheries for pollock, deepwater flatfish, and Pacific ocean perch account for most of the observed bycatch of coral, while rockfish fisheries account for little of the bycatch of sea anemones or of sea whips and sea pens.

The bottom trawl fisheries for Pacific ocean perch and Pacific cod and the pot fishery for Pacific cod accounts for most of the observed bycatch of sponges (Table 6-25).

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: The directed slope rockfish trawl fisheries begin in July concentrated in known areas of abundance and typically lasts only a few weeks. The annual exploitation rates on rockfish are thought to be quite low. Insemination is likely in the fall or winter, and parturition is likely mostly in the spring. Hence, reproductive activities are probably not directly affected by the commercial fishery.

Fishery-specific effects on amount of large size target fish: No evidence for tar- getting large fish

Fishery contribution to discards and offal production: Fishery discard rates of slope rockfish during 2000-2002 have been 7 - 11% for Pacific ocean perch, 9 - 18% for northern rockfish, 21 - 30 % for shortraker and rougheye rockfish, and 48 - 53% for other slope rockfish. The discard amount of species other than slope rockfish in the slope rockfish fishery has not been determined..

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: unknown.

Fishery-specific effects on EFH non-living substrate: unknown, but the heavy-duty "rockhopper" trawl gear commonly used in the fishery can move around rocks and boulders on the bottom.

6.8.3 Data Gaps and Research Priorities

There is little information on larval, post-larval, or early stages slope rockfish. Habitat requirements for larval, post-larval, and early stages are mostly unknown. Habitat requirements for later stage juvenile and adult fish are anecdotal or conjectural. Research needs to be done on the bottom habitat of the major fishing grounds, on what HAPC biota are found on these grounds, and on what impact bottom trawling has on these.

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Table 6-1.--Species comprising the slope rockfish assemblage in the Gulf of Alaska.

Common name	Scientific name	Management subgroup
Pacific ocean perch	*Sebastes alutus*	Pacific ocean perch
Shortraker rockfish	*S. borealis*	Shortraker/rougheye
Rougheye rockfish	*S. aleutianus*	Shortraker/rougheye
Northern rockfish	*S. polyspinis*	Northern rockfish
Sharpchin rockfish	*S. zacentrus*	Other slope rockfish
Redstripe rockfish	*S. proriger*	Other slope rockfish
Harlequin rockfish	*S. variegatus*	Other slope rockfish
Silvergrey rockfish	*S. brevispinis*	Other slope rockfish
Redbanded rockfish	*S. babcocki*	Other slope rockfish
Yellowmouth rockfish	*S. reedi*	Other slope rockfish
Bocaccio	*S.paucispinis*	Other slope rockfish
Greenstriped rockfish	*S. elongatus*	Other slope rockfish
Darkblotched rockfish	*S. crameri*	Other slope rockfish
Pygmy rockfish	*S. wilsoni*	Other slope rockfish
Splitnose rockfish	*S. diploproa*	Other slope rockfish
Aurora rockfish	*S. aurora*	Other slope rockfish
Blackgill rockfish	*S. melanostomus*	Other slope rockfish
Chilipepper	*S. goodei*	Other slope rockfish
Shortbelly rockfish	*S. jordani*	Other slope rockfish
Stripetail rockfish	*S. saxicola*	Other slope rockfish
Vermilion rockfish	*S. miniatus*	Other slope rockfish

Table 6-2a.–Commercial catch[a] (mt) of fish in the slope rockfish assemblage in the Gulf of Alaska, with Gulfwide values of acceptable biological catch (ABC) and fishing quotas[b] (mt), 1977-2002. Catches in 2002 updated through October 5, 2002.

Year	Fishery category	Regulatory area			Gulfwide	Gulfwide Management value	
		Western	Central	Eastern	Total	ABC	Quota
1977	Foreign	6,282	6,166	10,993	23,441		
	U.S.	0	0	12	12		
	JV	-	-	-	-		
	Total	6,282	6,166	11,005	23,453	50,000	30,000
1978	Foreign	3,643	2,024	2,504	8,171		
	U.S.	0	0	5	5		
	JV	-	-	-	-		
	Total	3,643	2,024	2,509	8,176	50,000	25,000
1979	Foreign	944	2,371	6,434	9,749		
	U.S.	0	99	6	105		
	JV	1	31	35	67		
	Total	945	2,501	6,475	9,921	50,000	25,000
1980	Foreign	841	3,990	7,616	12,447		
	U.S.	0	2	2	4		
	JV	0	20	0	20		
	Total	841	4,012	7,618	12,471	50,000	25,000
1981	Foreign	1,233	4,268	6,675	12,176		
	U.S.	0	7	0	7		
	JV	1	0	0	1		
	Total	1,234	4,275	6,675	12,184	50,000	25,000
1982	Foreign	1,746	6,223	17	7,986		
	U.S.	0	2	0	2		
	JV	0	3	0	3		
	Total	1,746	6,228	17	7,991	50,000	11,475
1983	Foreign	671	4,726	18	5,415		
	U.S.	7	8	0	15		
	JV	1,934	41	0	1,975		
	Total	2,612	4,775	18	7,405	50,000	11,475
1984	Foreign	214	2,385	0	2,599		
	U.S.	116	0	3	119		
	JV	1,441	293	0	1,734		
	Total	1,771	2,678	3	4,452	50,000	11,475
1985	Foreign	6	2	0	8		
	U.S.	631	13	181	825		
	JV	211	43	0	254		
	Total	848	58	181	1,087	11,474	6,083
1986	Foreign	Tr	Tr	0	Tr		
	U.S.	642	394	1,908	2,944		
	JV	35	2	0	37		
	Total	677	396	1,908	2,981	10,500	3,702
1987	Foreign	0	0	0	0		
	U.S.	1,347	1,434	2,088	4,869		
	JV	108	4	0	112		
	Total	1,455	1,438	2,088	4,981	10,500	5,000
1988	Foreign	0	0	0	0		
	U.S.	2,586	6,467	4,718	13,771		
	JV	4	5	0	8		
	Total	2,590	6,471	4,718	13,779	16,800	16,800
1989	U.S.	4,339	8,315	6,348	19,002	20,000	20,000
1990	U.S.	5,203	9,973	5,938	21,114	17,700	17,700

Table 6-2.--(Continued)

Year	Management subgroup	Regulatory area Western	Central	Eastern	Gulfwide Total	Gulfwide Management value ABC	Quota
1991	POP	1,589	2,956	2,087	6,631	5,800	5,800
	SR/RE	123	408	171	702	2,000	2,000
	Other slope	634	4,011	162	4,806	10,100	10,100
1992	POP	1,266	2,658	2,234	6,159	5,730	5,200
	SR/RE	115	1,367	683	2,165	1,960	1,960
	Other slope	1,068	7,495	875	9,438	14,060	14,060
1993	POP	477	1,140	443	2,060	3,378	2,560
	SR/RE	85	1,197	650	1,932	1,960	1,764
	Northern	902	3,778	145	4,825	5,760	5,760
	Other slope	342	2,423	2,658	5,423	8,300	5,383
1994	POP	165	920	768	1,853	3,030	2,550
	SR/RE	114	996	722	1,832	1,960	1,960
	Northern	1,394	4,519	55	5,968	5,760	5,760
	Other slope	101	715	797	1,613	8,300	2,235
1995	POP	1,422	2,598	1,722	5,742	6,530	5,630
	SR/RE	216	1,222	812	2,250	1,910	1,910
	Northern	113	5,476	45	5,634	5,270	5,270
	Other slope	31	883	483	1,397	7,110	2,235
1996	POP	987	5,145	2,246	8,378	8,060	6,959
	SR/RE	127	941	593	1,661	1,910	1,910
	Northern	173	3,146	24	3,343	5,270	5,270
	Other slope	19	618	244	881	7,110	2,020
1997	POP	1,832	6,720	979	9,531	12,990	9,190
	SR/RE	137	931	541	1,609	1,590	1,590
	Northern	62	2,870	15	2,947	5,000	5,000
	Other slope	68	941	208	1,217	5,260	2,170
1998	POP	850	7,501	610	8,961	12,820	10,776
	SR/RE	129	870	735	1,734	1,590	1,590
	Northern	67	2,974	10	3,051	5,000	5,000
	Other slope	46	701	114	861	5,260	2,170
1999	POP	1,935	7,910	627	10,472	13,120	12,590
	SR/RE	194	580	537	1,311	1,590	1,590
	Northern	574	4,825	c	5,399	4,990	4,990
	Other slope	39	614	135	788	5,270	5,270
2000	POP	1,160	8,379	618	10,157	13,020	13,020
	SR/RE	137	887	721	1,745	1,730	1,730
	Northern	747	2,578	c	3,325	5,120	5,120
	Other slope	49	363	165	577	4,900	4,900
2001	POP	944	9,249	624	10,817	13,510	13,510
	SR/RE	126	998	852	1,976	1,730	1,730
	Northern	539	2,588	c	3,127	4,880	4,880
	Other slope	25	318	216	559	4,900	1,010
2002	POP	2,720	8,261	748	11,729	13,190	13,190
	SR/RE	259	626	384	1,269	1,620	1,620
	Northern	337	2,997	c	3,334	4,980	4,980
	Other slope	218	397	49	664	5,040	990

Note: There were no foreign or joint venture catches after 1988. Catches prior to 1989 are landed catches only. Catches in 1989 and 1990 also include fish reported in weekly production reports as discarded by processors. Catches in 1991-2001 also include discarded fish, as determined through a "blend" of weekly production reports and information from the domestic observer program.

Definitions of terms: JV = Joint venture; Tr = Trace catches; POP = Pacific ocean perch management subgroup; SR/RE = shortraker/rougheye management subgroup; Other slope = other slope rockfish management subgroup (in 1991-92 consisted of all species in the slope rockfish assemblage except for Pacific ocean per and shortraker and rougheye rockfish; in 1993-2001 consisted of all species in the slope rockfish assemblag except for Pacific ocean perch and shortraker, rougheye, and northern rockfish); Northern = northern rockfish management subgroup.

[a]Catch defined as follows: 1977, all *Sebastes* rockfish for Japanese catch, and Pacific ocean perch for catches of other nations; 1978, Pacific ocean perch only; 1979-87, the 5 species comprising the Pacific oce perch complex; 1988-90, the 18 species comprising the slope rockfish assemblage; 1991-93, the 20 species comprising the slope rockfish assemblage; 1994-2002 the 21 species comprising the slope rockfish assemblage

[b]Quota defined as follows: 1977-86, optimum yield; 1987, target quota; 1988-2001 total allowable catch.

[c]Starting in 1999 in the Eastern area, northern rockfish is combined with other slope rockfish.

Sources: Catch: 1977-84, Carlson et al. (1986); 1985-88, Pacific Fishery Information Network (PacFIN), Pacific Marine Fisheries Commission, 305 State Office Building, 1400 S.W. 5th Avenue, Portland, OR 97201; 1989-2002, National Marine Fisheries Service, Alaska Region, P.O. Box 21668, Juneau, AK 99802. ABC and Quota: 1977-1986 Karinen and Wing (1987); 1987-2000, Heifetz et al. (2000); 2001 and 2002, North Pacific Fishery Management Council News and Notes, Vol. 6-01, Dec. 2001. 605 W. 4th Ave., Suite 306, Anchorage, Alaska 99501-2252.

Table 6-2b.–Catch (mt) of slope rockfish taken during research cruises in the Gulf of Alaska, 1977-2002. (Does not include catches in longline surveys before 1995; tr=trace)

Year	Pacific ocean perch	Shortraker/ rougheye	Northern rockfish	Other slope rockfish
1977	13.0	0.7	tr	0.8
1978	5.7	2.8	0.5	9.5
1979	12.2	1.9	1.0	0.4
1980	12.6	1.9	0.5	0.4
1981	57.1	12.5	8.4	16.3
1982	15.2	5.4	6.4	2.9
1983	2.4	3.2	1.7	0.1
1984	76.5	23.7	11.3	3.4
1985	35.2	10.5	10.8	1.7
1986	14.4	2.6	0.7	0.0
1987	68.8	28.1	40.6	19.8
1988	0.3	0.0	0.0	0.7
1989	1.0	0.6	0.2	0.1
1990	25.5	7.6	19.2	11.8
1991	0.1	tr	0.0	tr
1992	0.0	0.1	0.0	0.0
1993	59.2	12.8	20.8	11.3
1994	tr	0.1	0.0	0.0
1995	tr	tr	0.0	0.0
1996	81.2	23.1	12.5	16.9
1997	tr	26.6	0.0	0.0
1998	305.0	82.1	2.5	2.4
1999	330.2	145.4	13.2	51.6
2000	0.0	19.8	0.0	0.0
2001	42.5	16.9	23.4	0.7
2002	tr	11.9	0.0	tr

Table 6-3a.--Species composition (percent by weight) of the "other slope rockfish" management subgroup in the Gulf of Alaska commercial catch, 1992-2001, based on vessels that had observer coverage. (tr=trace; Redbanded rockfish is not included in the 1992 and 1993 data.)

	Regulatory area			
Species	Western	Central	Eastern	Gulf of Alaska
		1992		
Northern rockfish	92.9	88.7	14.8	82.3
Sharpchin rockfish	0.4	2.3	29.5	4.6
Redstripe rockfish	0.0	1.0	21.3	2.8
Harlequin rockfish	6.6	7.5	12.9	7.9
Silvergrey rockfish	tr	0.1	14.0	1.4
Yellowmouth rockfish	0.1	0.5	7.2	1.1
Other species	tr	tr	0.2	tr
		1993		
Northern rockfish	(removed from subgroup in 1993)			
Sharpchin rockfish	1.8	23.9	28.6	24.8
Redstripe rockfish	5.6	25.2	22.3	22.5
Harlequin rockfish	92.3	48.0	14.5	34.4
Silvergrey rockfish	tr	2.3	15.9	8.2
Yellowmouth rockfish	tr	0.7	18.1	9.2
Other species	0.2	tr	0.6	0.3
		1994		
Sharpchin rockfish	2.1	14.8	27.9	20.5
Redstripe rockfish	0.0	3.9	22.5	12.9
Harlequin rockfish	97.3	77.7	17.0	49.0
Silvergrey rockfish	0.0	0.6	26.9	13.6
Yellowmouth rockfish	0.1	0.9	4.2	2.5
Redbanded rockfish	0.5	2.0	1.0	1.4
Other species	tr	tr	0.5	0.2
		1995		
Sharpchin rockfish	6.1	26.0	23.0	24.5
Redstripe rockfish	1.5	6.4	29.2	14.1
Harlequin rockfish	73.1	63.6	17.2	47.8
Silvergrey rockfish	0.0	0.2	25.0	8.8
Yellowmouth rockfish	6.6	0.1	2.5	1.1
Redbanded rockfish	12.6	1.2	1.6	1.6
Other species	1.6	2.5	1.5	2.2

Table 6-3a.--(Continued).

Species	Regulatory area: Western	Central	Eastern	Gulf of Alaska
		1996		
Sharpchin rockfish	18.3	29.0	48.1	31.6
Redstripe rockfish	6.8	14.7	19.2	15.2
Harlequin rockfish	67.6	52.0	7.1	45.7
Silvergrey rockfish	0.0	0.6	2.8	0.9
Yellowmouth rockfish	0.0	tr	4.8	0.7
Redbanded rockfish	6.6	2.4	8.2	3.4
Other species	0.7	1.3	9.9	2.6
		1997		
Sharpchin rockfish	36.2	26.3	22.6	26.0
Redstripe rockfish	37.0	26.3	8.2	23.9
Harlequin rockfish	21.8	44.9	17.7	40.4
Silvergrey rockfish	0.0	1.5	11.2	2.8
Yellowmouth rockfish	0.5	tr	35.5	5.2
Redbanded rockfish	3.3	0.8	3.5	1.2
Other species	1.1	0.3	1.2	0.5
		1998		
Sharpchin rockfish	23.6	41.7	tr	37.0
Redstripe rockfish	0.5	1.2	51.4	5.9
Harlequin rockfish	72.5	52.1	35.8	51.5
Silvergrey rockfish	tr	0.6	3.7	0.9
Yellowmouth rockfish	0.0	tr	0.4	0.1
Redbanded rockfish	3.4	2.2	3.0	2.3
Other species	0.0	2.2	5.7	2.4
		1999		
Sharpchin rockfish	6.0	25.9	18.7	21.5
Redstripe rockfish	23.1	11.1	14.4	13.6
Harlequin rockfish	45.0	58.7	53.2	55.6
Silvergrey rockfish	0.0	0.7	10.1	2.4
Yellowmouth rockfish	0.0	0.1	1.0	0.3
Redbanded rockfish	1.5	3.2	2.1	2.7
Other species	24.3	0.2	0.5	4.0

Table 6-3a.--(Continued).

Species	Regulatory area: Western	Central	Eastern	Gulf of Alaska
		2000		
Sharpchin rockfish	0.0	56.0	24.6	47.4
Redstripe rockfish	0.8	6.5	33.4	8.9
Harlequin rockfish	91.2	26.3	25.7	32.2
Silvergrey rockfish	0.0	2.4	12.2	3.3
Yellowmouth rockfish	5.7	2.0	0.4	2.2
Redbanded rockfish	2.3	4.6	3.4	4.3
Other species	0.0	2.2	0.2	1.7
		2001		
Sharpchin rockfish	31.8	31.6	13.2	28.9
Redstripe rockfish	20.2	6.2	11.7	7.9
Harlequin rockfish	26.7	50.1	60.9	50.2
Silvergrey rockfish	0.0	3.6	2.8	3.2
Yellowmouth rockfish	19.2	0.2	0.7	1.5
Redbanded rockfish	2.0	6.0	10.3	6.4
Other species	0.0	2.3	0.3	1.9

Table 6-3b.–Species composition (percent by weight) of the "shortraker/rougheye management subgroup in the Gulf of Alaska commercial, 1992-2001, based on vessels that had observer coverage.

Species	Regulatory area: Western	Central	Eastern	Gulf of Alaska
		1992		
Shortraker rockfish	45.8	49.1	70.1	55.5
Rougheye rockfish	54.2	50.9	29.9	44.5
		1993		
Shortraker rockfish	73.3	62.7	82.8	69.9
Rougheye rockfish	26.7	37.3	17.2	30.1
		1994		
Shortraker rockfish	58.3	62.6	85.4	71.3
Rougheye rockfish	41.7	37.4	14.6	28.7
		1995		
Shortraker rockfish	44.3	65.8	81.1	69.3
Rougheye rockfish	55.7	34.2	18.9	30.7
		1996		
Shortraker rockfish	57.9	55.7	80.0	62.8
Rougheye rockfish	42.1	44.3	20.0	37.2
		1997		
Shortraker rockfish	82.5	52.8	78.6	63.6
Rougheye rockfish	17.5	47.2	21.4	36.4
		1998		
Shortraker rockfish	61.4	30.8	94.3	51.0
Rougheye rockfish	38.6	69.2	5.7	49.0
		1999		
Shortraker rockfish	79.7	62.6	85.1	72.5
Rougheye rockfish	20.3	37.4	14.9	27.5
		2000		
Shortraker rockfish	46.4	66.6	85.2	68.7
Rougheye rockfish	53.6	33.4	14.8	31.3
		2001		
Shortraker rockfish	45.8	65.8	78.5	66.9
Rougheye rockfish	54.2	34.2	21.5	33.1

Table 6-4. Fishery length frequency data for Pacific ocean perch in the Gulf of Alaska.

Length class (cm)	Year											
	1977	1978	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
<15	0	0	104	11	23	0	0	0	1	8	0	0
15	0	0	58	3	8	0	0	0	0	3	0	0
16	2	0	33	16	20	0	0	0	0	23	0	0
17	1	0	21	31	29	0	0	0	0	35	0	0
18	2	0	54	17	24	0	0	0	0	69	0	0
19	3	0	15	56	33	0	0	0	0	25	1	0
20	9	0	41	118	26	0	0	1	0	25	3	1
21	14	0	64	145	50	0	0	0	2	27	7	0
22	20	0	66	149	62	0	0	1	1	30	4	0
23	56	1	148	233	65	0	1	9	4	37	6	4
24	100	2	214	253	82	0	0	21	6	34	19	7
25	134	4	239	252	106	0	0	36	18	52	25	7
26	198	12	378	339	116	0	0	65	27	80	36	14
27	314	33	473	266	134	0	1	50	38	120	29	12
28	484	67	599	204	134	0	2	46	42	126	35	18
29	630	130	935	217	193	1	4	67	68	164	49	29
30	890	263	1,455	199	283	3	2	68	103	227	53	21
31	1,306	415	2,123	297	449	5	3	132	196	259	97	22
32	1,710	484	3,161	470	705	14	11	255	326	345	138	53
33	2,026	429	4,459	663	1,288	17	40	535	728	641	277	119
34	2,131	286	5,389	1,074	1,825	25	94	844	1,361	1,074	769	252
35-38	7,492	173	21,463	5,507	5,889	60	610	3,389	6,480	7,861	8,761	2,054
>38	1,866	0	10,181	3,387	1,519	5	128	1,043	1,462	3,312	3,210	720

Table 6 - 5. Fishery length frequency data for northern rockfish in the Gulf of Alaska.

Length class (cm)	Year												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
15-24	8	4	0	2	1	42	1	8	18	7	91	8	9
25	8	9	1	4	0	47	2	34	2	5	11	1	1
26	4	21	3	10	1	74	0	72	6	13	20	10	4
27	18	33	4	11	5	97	3	106	5	15	21	16	9
28	36	64	17	23	14	88	5	109	9	7	44	24	19
29	73	110	38	57	29	110	9	109	14	7	43	57	29
30	80	288	78	112	57	134	30	90	24	15	62	79	76
31	96	529	173	248	135	164	26	57	23	20	81	88	115
32	151	967	385	484	246	222	66	62	60	37	132	110	198
33	207	1,733	670	830	568	453	162	108	109	80	148	129	204
34	333	2,550	1,247	1,132	946	864	351	206	211	122	189	143	168
35	547	2,741	1,912	1,631	1,421	1,364	706	426	475	173	218	174	158
36	800	2,008	2,162	1,754	1,623	1,652	1,026	618	891	361	302	226	184
37	738	1,222	2,128	1,359	1,391	1,714	1,041	681	1,160	534	363	304	238
38	550	610	1,824	1,073	811	1,371	785	616	1,069	685	467	312	283
39	360	288	1,286	729	431	863	544	371	771	567	442	280	281
40	168	131	810	514	203	400	346	207	445	449	311	223	204
41	79	87	443	359	96	211	191	95	207	271	192	133	144
42	37	27	165	189	55	162	95	43	82	134	97	102	96
43	18	47	59	49	38	117	48	19	46	77	46	66	56
44	8	32	55	9	28	97	22	9	19	31	31	38	29
45-50	8	86	64	3	39	222	68	2	6	57	29	64	29
Total	4,327	13,587	13,524	10,582	8,138	10,468	5,527	4,048	5,652	3,667	3,340	2,587	2,534

Table 6-6.--Relative population number (RPN) and relative population weight (RPW) for rougheye and shortraker rockfish in the Gulf of Alaska domestic longline survey. Data are for the upper continental slope only, 201-1,000 m. depth (gullies are not included).

	Year														
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Rougheye RPN:															
Shumagin	2,663	5,355	4,832	3,670	7,425	6,774	3,923	9,487	5,686	7,027	5,983	6,303	10,748	8,237	9,359
Chirikof	937	1,922	1,034	1,091	970	1,507	743	1,476	1,009	1,244	1,163	1,670	2,021	4,489	1,749
Kodiak	2,523	3,198	5,522	5,005	4,196	4,028	1,951	4,526	4,494	4,290	5,065	4,987	7,852	4,068	4,438
Yakutat	2,921	4,092	3,557	4,934	4,097	5,100	2,973	4,169	4,616	4,945	3,753	5,512	5,294	4,388	4,711
Southeastern	4,453	9,322	5,390	11,370	4,996	6,027	10,184	7,555	10,224	16,922	9,632	11,132	13,461	7,441	7,089
Total	13,497	23,889	20,335	26,070	21,684	23,436	19,773	27,214	26,029	34,428	25,596	29,604	39,375	28,624	27,345
Rougheye RPW:															
Shumagin	3,177	6,609	5,352	3,914	7,681	6,303	3,970	11,624	5,519	8,095	6,872	6,273	10,787	8,245	10,878
Chirikof	1,185	2,414	1,281	1,287	1,279	1,743	914	1,787	1,375	1,619	1,527	2,053	2,416	5,616	2,182
Kodiak	2,786	3,751	6,409	5,338	4,504	4,091	1,994	4,728	4,621	4,224	5,598	4,900	7,705	4,407	4,059
Yakutat	3,815	5,116	4,398	6,480	4,513	5,025	3,313	4,394	5,069	5,495	4,271	5,629	6,051	4,105	5,030
Southeastern	5,975	13,069	7,412	15,555	6,871	8,807	15,593	10,311	14,001	23,754	12,728	14,372	19,450	10,765	9,763
Total	16,938	30,959	24,852	32,574	24,849	25,970	25,784	32,843	30,585	43,187	30,996	33,227	46,408	33,138	31,911
Shortraker RPN:															
Shumagin	4,492	3,272	3,015	3,074	1,660	1,523	2,549	5,765	4,098	2,888	4,630	5,011	9,481	5,150	3,386
Chirikof	1,290	858	773	776	572	229	613	531	646	918	973	823	1,298	1,031	951
Kodiak	2,332	2,691	3,476	2,412	1,374	1,067	1,040	1,325	2,231	2,200	2,498	3,078	2,904	3,703	1,982
Yakutat	5,830	6,492	9,281	10,575	9,130	7,121	5,222	7,992	8,409	12,408	15,295	13,394	13,995	14,177	9,942
Southeastern	1,420	1,972	1,403	2,247	1,479	2,199	1,862	2,427	1,967	2,459	3,258	3,167	4,025	2,646	3,098
Total	15,364	15,285	17,948	19,085	14,214	12,139	11,286	18,039	17,352	20,873	26,654	25,473	31,703	26,706	19,358
Shortraker RPW:															
Shumagin	4,869	4,301	5,004	5,953	2,078	2,192	3,956	7,940	5,946	4,468	6,716	6,954	15,050	7,314	4,978
Chirikof	2,591	1,449	1,216	1,384	914	293	1,174	812	1,007	1,471	1,422	1,165	1,607	1,682	1,324
Kodiak	5,043	5,833	6,787	4,874	2,802	1,912	2,649	2,554	4,657	4,273	5,201	5,562	5,553	7,413	3,305
Yakutat	13,320	13,335	19,093	20,585	17,033	14,411	11,046	15,248	17,352	26,830	30,685	26,500	28,754	28,382	18,314
Southeastern	2,474	3,384	2,214	3,546	2,053	4,124	3,102	4,034	3,377	3,970	5,818	4,569	7,099	4,574	5,598
Total	28,297	28,302	34,313	36,343	24,880	22,932	21,927	30,588	32,338	41,013	49,842	44,750	58,063	49,365	33,518

Table 6-7.--Estimated biomass (mt), by area, for slope rockfish in the 2001 biennial trawl survey of the Gulf of Alaska. Gulfwide 95% confidence bounds (mt) are also listed. Note: data in this table are for total biomass in the survey. For exploitable biomass, see Table 6-18.

	Statistical areas						95% Gulfwide Confidence Bounds	
Species	Shumagin	Chirikof	Kodiak	Yakutat*	South-eastern*	Gulfwide Total*	Lower*	Upper*
Pacific ocean perch	285,180	39,819	387,078	44,392	102,514	858,982	377,720	1,340,244
Shortraker rockfish	4,313	1,589	11,528	7,350	3,149	27,929	18,832	37,026
Rougheye rockfish	6,947	3,592	21,209	7,256	4,780	43,784	28,490	59,078
Shortraker/rougheye	11,260	5,182	32,737	14,606	7,929	71,713	53,918	89,508
Northern rockfish	93,538	24,490	237,131	117	0	355,275	0	776,946
Sharpchin rockfish	23	4	1,876	13,103	19,269	34,276	0	85,672
Redstripe rockfish	3	7	124	18	17,419	17,571	0	42,422
Harlequin rockfish	3,174	221	5,448	1,164	4,933	14,940	0	35,305
Silvergrey rockfish	0	16	44	3,545	20,424	24,029	13,739	34,318
Redbanded rockfish	61	51	308	1,308	4,686	6,414	0	15,068
Splitnose rockfish	0	0	0	1	2	2	0	10
Darkblotched rockfish	0	0	0	84	143	227	0	523
Greenstriped rockfish	0	0	0	8	354	362	137	587
Bocaccio	0	0	0	0	81	81	0	244
Pygmy rockfish	0	0	0	117	24	141	0	397
Yellowmouth rockfish	0	0	0	6	3,346	3,352	0	8,607
Total, other slope	3,260	299	7,800	19,357	70,695	101,411	39,101	163,721
Total, all species	393,238	69,789	664,746	78,468	181,123	1,387,365	744,250	2,030,513

*The 2001 survey did not sample the eastern Gulf of Alaska (the Yakutat and Southeastern areas). Substitute estimates of biomass for the Yakutat and Southeastern areas were obtained by averaging the biomass estimates for species in these areas in the 1993, 1996, and 1999 surveys. In the computations of variance to determine 95% confidence intervals, variance for the Yakutat and Southeastern areas was computed for each species using this formula: (variance of 1993, 1996, and 1999 biomass estimates in each area) x (1 + 1/3).

Table 6-8.--Comparison of biomass estimates (mt) for slope rockfish species in the Gulf of Alaska in the 1984, 1987, 1990, 1993, 1996, 1999, and 2001 trawl surveys. (Biomass estimates for 1993, 1996, and 1999 have been slightly revised from those listed in previous SAFE reports for slope rockfish.) Note: these are estimates of total biomass. For estimates of exploitable biomass for surveys since 1993, see Table 6-18.

Species	1984	1987	1990	1993	1996	1999	2001*
Pacific ocean perch	232,694	214,827	138,003	483,482	771,413	727,263	858,982
Shortraker rockfish	17,721	41,457	10,809	19,710	20,258	28,231	27,929
Rougheye rockfish	46,999	43,929	46,142	61,833	45,913	39,620	43,784
Subtotal, shortraker/rougheye	64,720	85,386	56,951	81,543	66,171	67,850	71,713
Northern rockfish	40,564	140,049	112,948	104,480	98,965	242,187	355,275
Sharpchin rockfish	7,219	70,160	37,050	23,676	64,570	20,841	34,276
Redstripe rockfish	4,803	23,706	24,681	29,619	14,964	8,226	17,571
Harlequin rockfish	2,442	63,833	17,194	9,281	19,974	9,877	14,940
Silvergrey rockfish	4,145	4,710	13,774	18,979	24,127	37,641	24,029
Redbanded rockfish	1,400	1,561	3,173	3,675	4,594	10,941	6,414
Darkblotched rockfish	6	33	184	291	121	272	227
Splitnose rockfish	0	2	3	0	0	7	2
Greenstriped rockfish	16	62	156	268	352	467	362
Vermilion rockfish	0	0	0	20	0	0	0
Bocaccio	502	38	176	106	137	0	81
Pygmy rockfish	0	366	76	3	283	187	141
Yellowmouth rockfish	516	241	1,900	3,563	923	5,570	3,352
Subtotal, other slope rockfish	21,049	164,712	98,367	89,480	130,044	94,027	101,394
Total, all species	359,027	604,974	406,269	758,985	1,066,593	1,131,327	1,387,364

*The 2001 survey did not sample the eastern Gulf of Alaska. Substitute estimates of biomass for this region in 2001 were obtained by averaging the eastern Gulf biomass estimates in the 1993, 1996, and 1999 surveys. These eastern Gulf of Alaska estimates have been included in the 2001 biomass estimates listed in this table.

Table 6-9.--Biomass estimates (mt) and Gulfwide confidence intervals for Pacific ocean perch in the Gulf of Alaska based on the 1984, 1987, 1990, 1993, 1996, 1999, and 2001 trawl surveys. (Biomass estimates and confidence intervals for 1993, 1996, and 1999 have been slightly revised from those listed in previous SAFE reports for slope rockfish.)

	Western	Central		Eastern		Total	95% Confidence interval
	Shumagin	Chirikof	Kodiak	Yakutat	South-eastern		
1984	59,710	9,672	36,976	94,055	32,280	232,694	101,550 - 363,838
1987	62,906	19,666	44,441	35,612	52,201	214,827	125,499 - 304,155
1990	24,375	15,991	15,221	35,635	46,780	138,003	70,993 - 205,013
1993	75,416	103,224	153,262	50,048	101,532	483,482	260,553 - 706,411
1996	92,618	140,479	326,280	50,394	161,641	771,413	355,756 - 1,187,069
1999	38,196	402,293	209,675	32,733	44,367	727,263	0 - 1,566,566
2001*	285,180	39,819	387,078	44,392	102,514	858,982	377,720 - 1,340,244

*The 2001 survey did not sample the eastern Gulf of Alaska (the Yakutat and Southeastern areas). Substitute estimates of biomass for the Yakutat and Southeastern areas were obtained by averaging the biomass estimates for Pacific ocean perch in these areas in the 1993, 1996, and 1999 surveys. The 2001 confidence interval was computed as noted previously in Table 6-7.

Table 6-10 . Survey age composition (% frequency) data for Pacific ocean perch in the Gulf of Alaska. Age compositions for 1978 and 1979 are based on surface reading of otoliths. Age compositions for 1980-99 are based on “break and burn” reading of otoliths.

Age class	Year										
	1978	1979	1980	1981	1982	1984	1987	1990	1993	1996	1999
2	16.08	0.00	0.00	0.14	0.00	0.81	0.73	0.52	0.69	1.72	0.60
3	0.24	0.55	0.39	0.40	0.00	0.53	4.63	6.03	1.97	1.61	2.03
4	1.04	0.81	3.32	5.94	0.17	12.51	6.70	10.90	2.42	3.54	4.54
5	0.63	2.69	5.78	3.42	4.24	2.76	6.18	7.18	7.43	4.25	5.16
6	1.89	5.72	3.01	3.34	8.63	3.82	9.45	12.61	10.98	6.22	2.56
7	6.08	14.52	2.10	2.10	5.27	8.03	19.34	15.54	14.77	3.73	4.06
8	12.02	21.94	7.01	1.34	1.41	38.37	7.30	9.45	11.44	8.72	5.91
9	11.32	17.34	8.37	2.59	3.77	4.01	8.36	7.26	12.77	14.32	9.46
10	9.63	10.72	15.51	6.49	5.47	2.20	10.91	7.88	7.62	18.32	5.40
11	5.42	7.51	9.75	16.93	7.06	0.76	11.40	3.58	4.88	10.91	11.38
12	4.79	4.49	6.40	15.90	11.07	1.98	2.10	2.50	7.55	7.93	14.37
13	5.06	2.72	4.91	5.76	9.52	1.53	1.12	2.55	3.05	3.40	8.61
14	5.44	2.30	2.57	4.19	6.64	1.71	1.02	4.99	1.94	3.60	6.66
15	4.76	1.89	3.24	3.01	4.46	0.66	0.78	1.18	1.82	2.73	4.55
16	4.50	1.66	2.81	1.68	2.39	0.34	0.86	1.01	0.80	0.57	3.99
17	3.57	1.45	1.53	1.03	1.54	1.09	1.27	0.50	3.05	1.27	2.28
18	3.36	1.21	1.69	0.73	1.35	0.71	0.45	0.44	0.62	0.86	1.33
19	2.01	0.91	1.88	1.39	1.00	0.24	0.31	0.47	0.19	1.34	0.32
20	0.92	0.61	1.54	2.75	2.26	0.45	0.36	0.60	0.22	1.29	1.22
21	0.68	0.48	1.83	0.29	1.39	0.39	0.30	0.40	0.14	0.34	0.69
22	0.24	0.28	1.24	0.48	0.79	0.17	0.16	0.15	0.55	0.38	0.79
23	0.12	0.12	0.35	0.70	0.05	0.42	0.18	0.21	0.23	0.25	1.16
24	0.19	0.07	0.86	0.39	0.78	0.20	0.09	0.14	0.33	0.00	0.45
25+	0.00	0.03	13.90	19.01	20.73	16.30	6.00	3.91	4.53	2.69	2.49

Table 6 -11. Survey age composition (% frequency) for northern rockfish in the Gulf of Alaska. All age compositions are based on "break and burn" reading of otoliths.

Age class	Year					
	1984	1987	1990	1993	1996	1999
2	0.00	0.00	0.00	0.03	0.28	0.00
3	0.00	0.30	0.06	0.28	0.30	0.03
4	0.00	1.67	0.19	0.31	0.13	0.16
5	1.48	5.18	2.91	0.85	0.21	1.05
6	4.10	3.84	5.42	1.07	1.13	0.27
7	8.91	2.89	2.65	1.09	0.58	0.94
8	18.34	0.29	4.08	6.34	2.07	0.89
9	10.83	2.85	5.38	11.98	4.10	4.23
10	5.08	10.15	4.47	6.53	5.31	2.77
11	4.63	11.24	5.77	10.31	8.52	7.92
12	2.59	11.25	3.52	4.44	7.58	6.92
13	7.23	3.46	5.36	4.90	7.72	5.42
14	6.81	4.32	8.24	4.02	4.02	5.62
15	6.35	1.42	9.71	2.44	3.29	7.82
16	4.05	3.71	5.08	5.19	3.87	9.16
17	1.98	10.43	5.08	3.14	1.65	1.56
18	1.90	4.15	0.67	3.97	3.41	7.21
19	0.59	8.10	1.12	2.81	5.44	1.88
20	0.76	2.76	6.56	0.40	8.78	1.30
21	0.32	2.59	6.63	2.32	2.77	3.00
22	1.01	0.71	4.58	3.41	3.06	2.19
23+	13.04	8.70	12.52	24.17	25.78	29.65

Table 6-12. Mortality rates, maximum age, and age of recruitment for slope rockfish. Area indicates location of study; West Coast of USA (WC), British Columbia (BC), Gulf of Alaska (GOA), Aleutians (AL), Bering Sea (BS). All mortality rates except where noted are for instantaneous rate of total mortality (Z) estimated with catch-curves.

Species	Mortality rate	Maximum age	Age of recruitment	Area	Reference
Pacific ocean	0.02-0.08	90	-	BC	1,2
perch	-	-	10	GOA	3
	-	84	-	GOA	4
	-	98	-	AL	5
Northern	0.06[a]	44	-	GOA	4
	-	57	-	AL	4
Rougheye	0.01-0.04	140	-	BC	1,2
	0.04	95	30	GOA	6,7
	0.030-0.039[b]	-	-	WC,BS,AL,GOA	8
Shortraker	-	120	-	BC	2
	0.027-0.042[b]	-	-	WC,BS,AL,GOA	8
Sharpchin	0.05	46	-	BC	1
	-	58	-	GOA	4
Yellowmouth	0.06	71	-	BC	1,2
Darkblotched	0.07	48	-	BC	1
Harlequin	-	43	-	BC	2
	-	34	-	GOA	4
Redstripe	0.1	41	-	BC	1,2
Silvergrey	0.01-0.07	80	-	BC	1,2
	-	75	-	GOA	4

1) Archibald et al. 1981; 2) Chilton and Beamish 1982; 3) Heifetz et al. 1994; 4) Malecha and Heifetz 2000; 5) Ito 1987; 6) Nelson and Quinn 1987; 7) Nelson 1986; 8) McDermott 1994. [a]The mortality rate for northern rockfish is for the instantaneous rate of natural mortality (M) estimated by the method of Alverson and Carney (1975). [b]M based on the gonad somatic index method (McDermott 1994).

Table 6-13a. Length-weight coefficients for some species of slope rockfish. Length-weight coefficients are the formula $W = aL^b$ where W = weight in kg and L = length in cm.

Species	Sex	a	b	Reference
Pacific ocean perch	combined	1.54×10^{-5}	2.95	1
	combined	1.91×10^{-5}	2.90	2
	males	1.57×10^{-5}	2.95	2
	females	2.04×10^{-5}	2.89	2
Northern	combined	1.63×10^{-5}	2.98	3
	combined	1.37×10^{-5}	3.04	2
	males	1.55×10^{-5}	2.99	2
	females	1.53×10^{-5}	3.01	2
Rougheye	combined	1.98×10^{-5}	2.94	2
	males	2.04×10^{-5}	2.94	2
	females	1.89×10^{-5}	2.97	2
Sharpchin	combined	1.13×10^{-5}	3.07	2
	males	8.89×10^{-6}	3.15	2
	females	1.19×10^{-5}	3.06	2
Shortraker	combined	9.85×10^{-6}	3.13	2
	males	1.26×10^{-5}	3.07	2
	females	1.02×10^{-5}	3.12	2

1) Ito 1982; 2) Martin 1997; 3) Clausen and Heifetz 1989.

Table 6-13b. Von Bertalanffy parameters for some species of slope rockfish, by area and sex. (BC = British Columbia; GOA = Gulf of Alaska; AL = Aleutian Islands; and BS = Eastern Bering Sea.)

Species	Area	Sex	t_0	k	L_{inf} (cm)	Reference
Pacific ocean perch	BC	combined	-8.22	0.088	44.80	1
	BC	combined	-5.22	0.126	42.60	1
	GOA	combined	-0.32	0.207	41.10	2
	GOA	combined	-0.37	0.204	40.74	3
	GOA	male	-0.29	0.220	39.56	3
	GOA	female	-0.41	0.191	42.00	3
	AL	combined	-0.82	0.169	39.24	3
	BS	combined	-1.66	0.140	39.96	3
Northern	GOA	combined	-1.51	0.190	35.60	2
	GOA	combined	-0.64	0.165	39.16	3
	GOA	male	-0.26	0.187	37.83	3
	GOA	female	-0.87	0.152	40.22	3
	AL	combined	-7.16	0.103	34.27	3
Rougheye	GOA	combined	-4.21	0.050	54.70	4
	GOA	combined	0.63	0.108	49.63	3
	GOA	male	1.14	0.119	49.79	3
	GOA	female	0.18	0.100	49.57	3
Sharpchin	BC	combined	-2.21	0.095	34.90	1
	GOA	combined	-0.81	0.131	32.64	3
	GOA	male	-0.48	0.167	28.44	3
	GOA	female	-0.75	0.122	35.02	3
Silvergray	GOA	combined	-1.68[a]	0.100	59.80	3
	GOA	male	-1.68[a]	0.110	57.14	3
	GOA	female	-1.68[a]	0.093	62.25	3
Harlequin	GOA	combined	-3.86	0.099	31.51	3
	GOA	male	-4.76	0.091	30.60	3
	GOA	female	-3.26	0.110	32.32	3

1) Archibald et al. 1981; 2) Heifetz and Clausen 1991; 3) Malecha and Heifetz 2000; 4) Nelson 1986.

[a]t_0 for silvergray rockfish could not be accurately estimated from the data, therefore t_0 was constrained at the average value for all other rockfish species.

Table 6-14. Estimated time series of female spawning biomass, 6+ biomass (age 6 and greater), catch/6 + biomass, and number of age two recruits for Pacific ocean perch in the Gulf of Alaska. Estimates are shown for the current assessment and from the previous SAFE.

Year	Spawning biomass (mt)		6+ Biomass (mt)		catch/6+ biomass		Age two recruits (1000's)	
	Current	Previous	Current	Previous	Current	Previous	Current	Previous
1977	48,907	51,489	141,950	148,200	0.152	0.146	22,517	23,921
1978	43,760	46,419	125,765	132,071	0.064	0.061	38,014	43,853
1979	43,432	46,075	123,057	129,438	0.068	0.065	60,901	63,028
1980	42,761	45,446	120,099	126,628	0.091	0.086	26,518	27,533
1981	40,900	43,603	115,668	122,511	0.092	0.086	26,667	27,544
1982	39,041	41,801	116,290	124,799	0.047	0.044	47,485	49,944
1983	39,482	42,403	129,758	139,038	0.022	0.021	34,679	36,172
1984	41,747	44,848	137,442	147,181	0.021	0.019	29,138	30,150
1985	44,259	47,571	144,924	155,013	0.006	0.005	36,849	37,353
1986	47,989	51,542	160,221	171,071	0.014	0.013	49,830	49,525
1987	52,157	56,014	170,829	182,174	0.027	0.025	50,326	49,881
1988	55,888	60,045	177,172	188,836	0.049	0.046	159,199	133,320
1989	58,139	62,563	181,092	192,875	0.066	0.062	80,177	66,079
1990	59,069	63,716	185,422	197,020	0.070	0.066	45,291	37,889
1991	59,642	64,447	189,242	200,520	0.035	0.033	42,186	35,027
1992	62,590	67,482	232,133	235,470	0.027	0.027	36,468	32,457
1993	68,233	72,603	257,436	255,080	0.008	0.008	32,123	30,978
1994	76,017	79,614	277,060	270,560	0.007	0.007	28,812	29,758
1995	84,788	87,302	294,249	283,729	0.020	0.021	26,614	29,898
1996	93,210	94,210	303,904	290,429	0.028	0.029	33,679	41,533
1997	101,074	100,260	307,698	292,429	0.031	0.033	42,751	52,370
1998	107,773	105,102	307,613	291,581	0.030	0.031	43,633	48,613
1999	112,964	108,677	305,958	290,293	0.035	0.036	47,125	49,082
2000	115,830	110,270	303,597	290,112	0.034	0.035	60,147	62,472
2001	117,186	110,909	303,634	293,420	0.036	0.038	62,901	63,724
2002	117,090	107,072	303,281	312,240	0.039		63,966	45,090
2003*	112,269		298,816				47,840	

* projection based on an average recruitment 1977-1993 year class.

Table 6-15. Estimated numbers (thousands) in 2003, fishery selectivity, and survey selectivity of Pacific ocean perch in the Gulf of Alaska. Also shown are schedules of age specific weight and female maturity.

Age	Numbers in 2003 (1000's)	Percent mature	Weight (g)	Fishery selectivity	Survey selectivity
2	47,839	0	53	0	7
3	67,257	0	116	1	16
4	62,922	0	194	3	32
5	57,263	0	279	10	58
6	42,742	0	363	28	85
7	37,777	12	442	63	100
8	35,370	20	515	99	100
9	26,272	30	579	100	99
10	19,037	42	635	99	97
11	18,911	56	683	99	97
12	19,398	69	724	99	97
13	20,312	79	759	99	97
14	21,734	87	788	99	97
15	21,709	92	812	99	97
16	35,964	95	832	99	97
17	66,752	97	848	99	97
18	19,477	98	861	99	97
19	17,502	99	872	99	97
20	11,584	99	881	99	97
21	8,143	100	889	99	97
22	8,741	100	895	99	97
23	10,999	100	900	99	97
24	5,757	100	904	99	97
25+	5,358	100	907	99	97

Table 6 -16. Estimated time series of female spawning biomass, total exploitable biomass, 6+ biomass (age 6 and greater), catch/(6+ biomass), and the number of age two recruits for northern rockfish in the Gulf of Alaska based an age structured model.

Year	Spawning biomass (mt)		Total exploitable biomass (mt)		6+ Total Biomass (mt)		Catch / (6+ Total biomass)		Age two recruits (1000's)	
	Current	Previous	Current	Previous	Current	Previous	Current	Previous	Current	Previous
1977	26,000	24,561	78,831	73,844	99,101	93,550	0.006	0.007	36,814	34,467
1978	26,926	25,420	87,047	81,519	100,792	95,106	0.005	0.006	68,465	65,016
1979	28,343	26,743	95,277	89,373	106,701	100,622	0.006	0.007	25,403	23,400
1980	30,170	28,451	101,701	95,507	108,524	102,320	0.007	0.008	11,129	10,843
1981	32,315	30,456	106,703	100,396	115,441	108,741	0.013	0.014	10,545	10,389
1982	34,480	32,467	109,878	103,172	128,766	121,310	0.030	0.032	21,998	20,512
1983	35,928	33,753	111,987	104,793	131,792	123,833	0.027	0.029	25,126	24,704
1984	37,398	35,060	115,432	107,759	131,703	123,614	0.008	0.008	37,781	34,532
1985	39,628	37,137	121,695	113,598	133,230	125,108	0.001	0.001	17,799	16,923
1986	42,091	39,450	128,166	119,873	137,188	128,814	0.002	0.002	64,377	58,457
1987	44,477	41,693	132,639	124,303	141,378	132,995	0.003	0.003	21,298	19,669
1988	46,736	43,816	135,424	126,929	147,880	138,927	0.007	0.008	12,648	11,748
1989	48,670	45,620	138,006	129,241	149,700	140,629	0.010	0.011	21,919	20,054
1990	50,321	47,146	141,206	132,055	160,605	150,367	0.011	0.011	21,181	18,484
1991	51,754	48,459	144,984	135,356	163,303	152,674	0.028	0.030	3,338	3,114
1992	52,010	48,598	146,159	136,031	160,847	150,017	0.048	0.052	17,020	15,134
1993	51,050	47,510	144,089	133,469	156,553	145,373	0.031	0.033	2,549	2,178
1994	50,942	47,275	143,464	132,474	154,588	142,913	0.039	0.042	5,741	4,664
1995	50,374	46,568	140,199	129,032	147,523	135,872	0.038	0.041	3,940	3,382
1996	49,786	45,835	135,477	124,150	142,970	131,068	0.023	0.026	18,152	17,540
1997	49,789	45,700	132,220	120,777	137,430	125,618	0.021	0.023	18,997	17,540
1998	49,678	45,463	128,548	117,078	132,398	120,587	0.023	0.025	18,997	17,540
1999	49,187	44,864	123,940	112,494	126,541	114,873	0.043	0.047	18,997	17,540
2000	47,387	42,982	116,535	105,138	121,163	108,775	0.027	0.031	18,997	17,540
2001	46,076	41,615	111,020	99,686	115,141	103,005	0.027	0.030	18,997	17,540
2002	44,573	40,067	105,611	94,354	109,202	97,446	0.031		18,997	17,540
2003*	42,743		105,263		108,834				18,997	

* projection based on an average recruitment 1977-1994 year class.

Table 6-17. Estimated numbers (thousands) in 2003, fishery selectivity (assumed equal to survey selectivity) of northern rockfish in the Gulf of Alaska based on an age structured model. Also shown are schedules of age specific weight and female maturity.

Age	Numbers (1000's)	Percent mature	Weight (g)	Fishery/Survey selectivity
2	18,997	1	63	2
3	6,725	2	103	4
4	5,660	3	153	8
5	3,867	4	210	15
6	2,924	6	273	25
7	2,766	9	336	38
8	12,286	13	399	55
9	2,467	18	458	75
10	3,305	25	512	91
11	1,342	33	561	100
12	8,170	43	603	100
13	1,461	52	641	100
14	8,456	62	672	100
15	7,978	71	699	100
16	4,188	78	722	100
17	6,413	84	740	100
18	17,660	89	756	100
19	4,467	92	769	100
20	8,723	95	780	100
21	5,371	96	788	100
22	4,379	97	795	100
23+	52,957	98	801	100

Table 6-18.--Estimates of exploitable biomass of shortraker and rougheye rockfish and other slope rockfish in the Gulf of Alaska, by NPFMC regulatory area, based on the 1993 - 2001 triennial trawl surveys. Results of the age structured modeling are used to determine exploitable biomass of Pacific ocean perch and northern rockfish.

	Exploitable biomass (mt)			
Species	Western	Central	Eastern	Total
		1993		
Shortraker rockfish	2,726	7,636	8,588	18,950
Rougheye rockfish	11,230	42,326	9,854	63,410
Subtotal, shortraker/rougheye	13,956	49,962	18,442	82,360
Sharpchin rockfish	22	7,943	14,490	22,455
Redstripe rockfish	0	111	26,620	26,731
Harlequin rockfish	30	8,060	530	8,619
Silvergrey rockfish	0	448	16,433	16,880
Redbanded rockfish	11	444	3,089	3,544
Minor species	0	0	4,105	4,105
Subtotal, other slope rockfish	63	17,006	65,267	82,334
		1996		
Shortraker rockfish	1,906	10,134	8,221	20,261
Rougheye rockfish	3,404	27,405	13,803	44,612
Subtotal, shortraker/rougheye	5,310	37,539	22,024	64,873
Sharpchin rockfish	39	2,015	62,579	64,633
Redstripe rockfish	0	89	14,722	14,811
Harlequin rockfish	772	1,937	16,372	19,081
Silvergrey rockfish	0	1,555	22,478	24,033
Redbanded rockfish	61	203	4,298	4,562
Minor species	152	20	4,036	4,208
Subtotal, other slope rockfish	1,024	5,819	124,485	131,328
		1999		
Shortraker rockfish	2,208	12,391	13,633	28,232
Rougheye rockfish	6,036	18,781	12,373	37,189
Subtotal, shortraker/rougheye	8,244	31,172	26,005	65,421
Sharpchin rockfish	0	2,857	17,985	20,842
Redstripe rockfish	0	125	8,077	8,201
Harlequin rockfish	7	8,560	1,307	9,874
Silvergrey rockfish	0	6,746	30,755	37,500
Redbanded rockfish	118	404	10,421	10,943
Minor species	0	6	6,483	6,489
Subtotal, other slope rockfish	126	18,698	75,027	93,850

Table 6-18.– (Continued).

	Exploitable biomass (mt)			
Species	Western	Central	Eastern	Total
		2001*		
Shortraker rockfish	4,313	13,117	10,499	27,929
Rougheye rockfish	6,851	23,366	11,818	42,035
Subtotal, shortraker/rougheye	11,164	36,484	22,317	69,964
Sharpchin rockfish	23	1,880	32,372	34,276
Redstripe rockfish	0	131	17,433	17,564
Harlequin rockfish	3172	5,625	6098	14,894
Silvergrey rockfish	0	16	23,888	23,095
Redbanded rockfish	61	309	5,983	6,352
Minor species	0	0	4,160	4,160
Subtotal, other slope rockfish	3256	7,961	89,934	101,151

* Values for Eastern Gulf are the averages of 93, 96, and 99 values.

Table 6-19. Set of projections of spawning biomass (SB) and yield for Pacific ocean perch in the Gulf of Alaska . This set of projections encompasses seven harvest scenarios is designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For a description of scenarios see section 6.7.1. All units in mt. $B_{40\%}$ = 104,820 mt, $B_{35\%}$ = 91,710 mt, $F_{40\%}$ = 0.050, and $F_{35\%}$ = 0.060.

Year	Maximum permissible F	Authors F	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
Spawning biomass (mt)							
2002	113,570	113,570	113,570	113,570	113,570	113,570	113,570
2003	112,269	112,269	113,196	113,022	114,130	111,912	112,269
2004	110,194	110,194	113,854	113,160	117,636	108,808	110,194
2005	108,588	108,588	114,917	113,705	121,618	106,231	108,243
2006	107,490	107,490	116,427	114,699	126,119	104,229	106,142
2007	107,192	107,192	118,707	116,461	131,495	103,113	104,875
2008	107,185	107,185	121,244	118,477	137,217	102,385	103,946
2009	107,552	107,552	124,124	120,833	143,371	102,098	103,464
2010	108,127	108,127	127,163	123,352	149,748	102,067	103,248
2011	108,681	108,681	130,101	125,778	156,044	102,061	103,071
2012	109,054	109,054	132,737	127,920	162,001	101,931	102,787
2013	109,185	109,185	134,984	129,696	167,492	101,626	102,348
2014	109,133	109,133	136,888	131,155	172,539	101,208	101,814
2015	108,964	108,964	138,509	132,361	177,187	100,741	101,247
Fishing mortality							
2002	0.042	0.042	0.042	0.042	0.042	0.042	0.042
2003	0.050	0.050	0.025	0.030	0.000	0.060	0.050
2004	0.050	0.050	0.025	0.030	0.000	0.060	0.050
2005	0.050	0.050	0.025	0.030	0.000	0.060	0.060
2006	0.050	0.050	0.025	0.030	0.000	0.059	0.060
2007	0.050	0.050	0.025	0.030	0.000	0.059	0.060
2008	0.050	0.050	0.025	0.030	0.000	0.058	0.059
2009	0.050	0.050	0.025	0.030	0.000	0.058	0.059
2010	0.050	0.050	0.025	0.030	0.000	0.058	0.059
2011	0.050	0.050	0.025	0.030	0.000	0.058	0.058
2012	0.050	0.050	0.025	0.030	0.000	0.058	0.058
2013	0.050	0.050	0.025	0.030	0.000	0.057	0.058
2014	0.050	0.050	0.025	0.030	0.000	0.057	0.057
2015	0.050	0.050	0.025	0.030	0.000	0.057	0.057
Yield (mt)							
2002	11,572	11,572	11,572	11,572	11,572	11,572	11,572
2003	13,663	13,663	6,913	8,188	0	16,237	13,663
2004	13,621	13,621	7,052	8,317	0	16,043	13,621
2005	13,703	13,703	7,248	8,513	0	16,006	16,284
2006	13,892	13,892	7,494	8,770	0	16,014	16,364
2007	14,079	14,079	7,734	9,020	0	15,945	16,448
2008	14,174	14,174	7,924	9,210	0	15,848	16,289
2009	14,158	14,158	8,049	9,326	0	15,706	16,079
2010	14,130	14,130	8,161	9,427	0	15,598	15,905
2011	14,097	14,097	8,262	9,517	0	15,486	15,734
2012	14,053	14,053	8,351	9,595	0	15,349	15,549
2013	13,999	13,999	8,433	9,664	0	15,191	15,355
2014	13,933	13,933	8,504	9,724	0	15,025	15,160
2015	13,867	13,867	8,572	9,781	0	14,873	14,984

Table 6-20. Percentage of exploitable biomass by area for slope rockfish based on the 1993, 96, 99 and 2001 triennial trawl surveys. Weighted average uses weights of 4:6:9 for the 1996, 1999,and 2001 survey, respectively.

	Western	Central	Eastern
1993			
Pacific ocean perch	16.67%	56.26%	27.12%
Rougheye/shortraker rockfish	16.95%	60.66%	22.34%
Northern rockfish	3.71%	96.25%	0.04%
Other slope rockfish	0.08%	20.65%	79.27%
1996			
Pacific ocean perch	11.48%	61.11%	27.41%
Rougheye/shortraker rockfish	8.19%	57.87%	33.95%
Northern rockfish	26.28%	73.51%	0.21%
Other slope rockfish	0.78%	4.43%	94.79%
1999			
Pacific ocean perch	5.00%	84.37%	10.63%
Rougheye/shortraker rockfish	12.60%	47.65%	39.75%
Northern rockfish	6.78%	93.18%	0.04%
Other slope rockfish	0.13%	19.92%	79.94%
2001*			
Pacific ocean perch	33.37%	48.28%	18.35%
Rougheye/shortraker rockfish	15.96%	52.15%	31.90%
Northern rockfish	17.83%	82.14%	0.03%
Other slope rockfish	3.22%	7.87%	88.91%
Weighted average			
Pacific ocean perch	19.85%	62.28%	17.87%
Rougheye/shortraker rockfish	13.31%	51.91%	34.78%
Northern rockfish	16.16%	83.76%	0.08%
Other slope rockfish	1.73%	10.95%	87.31%

* Values for Eastern Gulf are the averages of 93, 96, 99 values.

Table 6-21. Northern rockfish spawning biomass, fishing mortality, and yield for seven harvest scenarios. B40% = 25,268 mt, B35% = 22,109 mt, F40% = 0.056, F35% = 066.

Year	Maximum permissible F	Author's F	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished?
Spawning biomass (mt)							
2002	44,573	44,573	44,573	44,573	44,573	44,573	44,573
2003	42,743	42,743	42,743	42,743	42,743	42,743	42,743
2004	39,920	39,920	41,034	41,210	42,181	39,500	39,920
2005	37,177	37,177	39,275	39,610	41,493	36,402	37,177
2006	34,563	34,563	37,516	37,994	40,724	33,493	34,200
2007	32,144	32,144	35,828	36,434	39,942	30,834	31,477
2008	29,923	29,923	34,220	34,939	39,151	28,425	29,006
2009	27,971	27,971	32,781	33,597	38,449	26,326	26,849
2010	26,317	26,317	31,553	32,455	37,889	24,558	25,028
2011	24,965	24,965	30,561	31,538	37,506	23,165	23,563
2012	23,948	23,948	29,828	30,874	37,342	22,168	22,502
2013	23,277	23,277	29,375	30,486	37,438	21,526	21,806
2014	22,897	22,897	29,171	30,346	37,776	21,173	21,406
2015	22,759	22,759	29,199	30,437	38,352	21,056	21,249
Fishing mortality							
2002	0.033	0.033	0.033	0.033	0.033	0.033	0.033
2003	0.056	0.056	0.028	0.024	0.000	0.066	0.056
2004	0.056	0.056	0.028	0.024	0.000	0.066	0.056
2005	0.056	0.056	0.028	0.024	0.000	0.066	0.066
2006	0.056	0.056	0.028	0.024	0.000	0.066	0.066
2007	0.056	0.056	0.028	0.024	0.000	0.066	0.066
2008	0.056	0.056	0.028	0.024	0.000	0.066	0.066
2009	0.056	0.056	0.028	0.024	0.000	0.066	0.066
2010	0.056	0.056	0.028	0.024	0.000	0.064	0.065
2011	0.054	0.054	0.028	0.024	0.000	0.060	0.062
2012	0.052	0.052	0.028	0.024	0.000	0.058	0.059
2013	0.051	0.051	0.028	0.024	0.000	0.056	0.057
2014	0.050	0.050	0.028	0.024	0.000	0.055	0.056
2015	0.049	0.049	0.028	0.024	0.000	0.055	0.055
Yield (mt)							
2002	3,339	3,339	3,339	3,339	3,339	3,339	3,339
2003	5,274	5,274	2,673	2,264	0	6,254	5,274
2004	4,897	4,897	2,550	2,169	0	5,747	4,897
2005	4,544	4,544	2,429	2,075	0	5,279	5,388
2006	4,221	4,221	2,315	1,985	0	4,855	4,954
2007	3,955	3,955	2,222	1,912	0	4,509	4,597
2008	3,751	3,751	2,153	1,859	0	4,242	4,320
2009	3,611	3,611	2,111	1,829	0	4,056	4,126
2010	3,535	3,535	2,099	1,823	0	3,830	3,951
2011	3,438	3,438	2,110	1,836	0	3,587	3,695
2012	3,324	3,324	2,135	1,862	0	3,446	3,535
2013	3,260	3,260	2,166	1,892	0	3,379	3,452
2014	3,241	3,241	2,199	1,924	0	3,368	3,428
2015	3,259	3,259	2,234	1,958	0	3,399	3,447

Table 6-22. Set of projections of yield for slope rockfish for 2003 in the Gulf of Alaska. This set of projections encompasses scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA). For a description of scenarios see section 6.7.1. All units in mt.

	Exploitable	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Species	Biomass	F	Yield	F	Yield	F	Yield	F	Yield
Shortraker	25,473	0.0225	573	0.0225	573	0.0113	287		
Rougheye	41,356	0.0320	1,323	0.0250	1,034	0.0160	662		
Total shortraker rougheye	66,829		1,896		1,607		949	0.025	1,671
Sharpchin	39,884	0.053	2,114	0.050	1,994	0.027	1,077		
Redstripe	13,576	0.075	1,018	0.075	1,018	0.038	516		
Harlequin	14,594	0.045	657	0.045	657	0.023	336		
Silvergrey	28,477	0.030	854	0.030	854	0.015	427		
Redbanded	7,284	0.045	328	0.045	328	0.023	168		
Minor spp	4,147	0.045	187	0.045	187	0.023	96		
Total other slope rockfish	**107,962**		**5,157**		**5,038**		**2,618**	**0.010**	**1,012**

Table 6-23. Summary of computations of ABC's and overfishing levels for slope rockfish for 2003. Since ABC's and overfishing levels are based on subgroups, individual species are shown only for illustrative purposes.

Species	Exploitable biomass (mt)	ABC F	ABC Yield (mt)	Overfishing F	Overfishing Yield (mt)
Pacific ocean perch	298,816*	$F=F_{40\%}$=.050	13,660	F=F35%=0.060	16,240
Shortraker rockfish	25,473	F=0.75M=0.023	586	F=M=0.030	764
Rougheye rockfish	41,356	F=M=0.025	1,034	F35%=0.038	1,579
Subtotal rougheye/shortraker	66,829		1,620		2,343
Northern rockfish	108,834*	$F=F_{40\%}$=0.056	5,540	F35%=0.066	6,560
Sharpchin rockfish	39,884	F=M=0.050	1,994	F35%=0.064	2,553
Redstripe rockfish	13,576	F=0.75M=0.075	1,018	F=M=0.100	1,358
Harlequin rockfish	14,594	F=0.75M=0.045	657	F=M=0.060	876
Silvergrey rockfish	28,477	F=0.75M=0.030	854	F=M=0.040	1,139
Redbanded rockfish	7,284	F=0.75M=0.045	328	F=M=0.060	437
Minor species	4,147	F=0.75M=0.045	187	F=M=0.060	249
Subtotal other slope rockfish	107,962		5,038		6,612
Total	582,441		25,858		31,755

* Age 6 and greater biomass

Table 6-24.-- Analysis of ecosystem considerations for slope rockfish.

Indicator	***Observation***	***Interpretation***	***Evaluation***
ECOSYSTEM EFFECTS ON STOCK			
Prey availability or abundance trends	important for larval and post-larval survival, but no information known	may help to determine year class strength	possible concern if some information available
Predator population trends	unknown		little concern for adults
Changes in habitat quality	variable	variable recruitment	possible concern
FISHERY EFFECTS ON ECOSYSTEM			
Fishery contribution to bycatch			
Prohibited species	unknown		
Forage (including herring, Atka mackerel, cod, and pollock)	unknown		
HAPC biota (seapens/whips, corals, sponges, anemones)	fishery disturbing hard-bottom biota, i.e., corals, sponges	could harm the ecosys-tem by reducing shelter for some species	concern
Marine mammals and birds	probably few taken		little concern
Sensitive non-target species	corals and sponges		concern
Fishery concentration in space and time	little overlap between fishery and reproductive activities	fishery does not hinder reproduction	little concern
Fishery effects on amount of large size target fish	no evidence for tar-getting large fish	large fish and small fish are both in population	little concern

Indicator	*Observation*	*Interpretation*	*Evaluation*
Fishery contribution to discards and offal production	discard rates moderate to high for some species of slope rockfish	little unnatural input of food into the ecosystem	some concern
Fishery effects on age-at-maturity and fecundity	**fishery is catching some immature fish**	**could reduce spawning potential and yield**	possible concern

Table 6-25. Average bycatch (kg) and bycatch rates during 1997 - 99 of living substrates in the Gulf of Alaska; POT - pot gear; BTR - bottom trawl; HAL - Hook and line (source - Draft Programmatic SEIS).

		Bycatch (kg)				Target	Bycatch rate (kg/mt target)			
Target fishery	Gear	Coral	Anemone	Sea whips	Sponge	catch (mt)	Coral	Anemone	Sea whips	Sponge
Arrowtooth flounder	POT	0	0	0	0	4	0.0000	0.0000	0.0000	0.0000
Arrowtooth flounder	BTR	58	99	13	24	2,097	0.0276	0.0474	0.0060	0.0112
Deep water flatfish	BTR	1,626	481	5	733	2,001	0.8124	0.2404	0.0024	0.3663
Rex sole	BTR	321	306	11	317	2,157	0.1488	0.1417	0.0053	0.1468
Shallow water flatfish	POT	0	0	0	0	5	0.0000	0.0000	0.0000	0.0000
Shallow water flatfish	BTR	53	4,741	115	403	2,024	0.0261	2.3420	0.0567	0.1993
Flathead sole	BTR	3	267	1	136	484	0.0071	0.5522	0.0019	0.2806
Pacific cod	HAL	28	4,419	961	33	10,765	0.0026	0.4105	0.0893	0.0030
Pacific cod	POT	0	14	0	1,724	12,863	0.0000	0.0011	0.0000	0.1340
Pacific cod	BTR	34	5,767	895	788	37,926	0.0009	0.1521	0.0236	0.0208
Pollock	BTR	1,153	55	0	23	2,465	0.4676	0.0222	0.0000	0.0092
Pollock	PTR	41	110	0	0	97,171	0.0004	0.0011	0.0000	0.0000
Demersal shelf rockfish	HAL	0	0	0	141	226	0.0000	0.0000	0.0000	0.6241
Northern rockfish	BTR	25	90	0	103	1,938	0.0127	0.0464	0.0000	0.0532
Other slope rockfish	HAL	0	0	0	0	14	0.0000	0.0000	0.0000	0.0000
Other slope rockfish	BTR	0	0	0	0	193	0.0000	0.0000	0.0000	0.0000
Pelagic shelf rockfish	HAL	0	0	0	0	203	0.0000	0.0000	0.0000	0.0000
Pelagic shelf rockfish	BTR	324	176	3	245	1,812	0.1788	0.0969	0.0017	0.1353
Pacific ocean perch	BTR	549	90	5	1,968	6,564	0.0837	0.0136	0.0007	0.2999
Pacific ocean perch	PTR	7	0	0	55	1,320	0.0052	0.0000	0.0000	0.0416
Shortraker/rougheye	HAL	6	0	0	0	19	0.3055	0.0000	0.0000	0.0000
Shortraker/rougheye	BTR	0	18	0	0	21	0.0000	0.8642	0.0000	0.0000
Sablefish	HAL	156	154	68	27	11,143	0.0140	0.0138	0.0061	0.0025
Sablefish	BTR	0	0	0	0	27	0.0000	0.0000	0.0000	0.0000
Shortspine thornyhead	HAL	0	0	0	0	2	0.0000	0.0000	0.0000	0.0000
Shortspine thornyhead	BTR	0	9	0	1	2	0.0000	4.8175	0.0000	0.4069

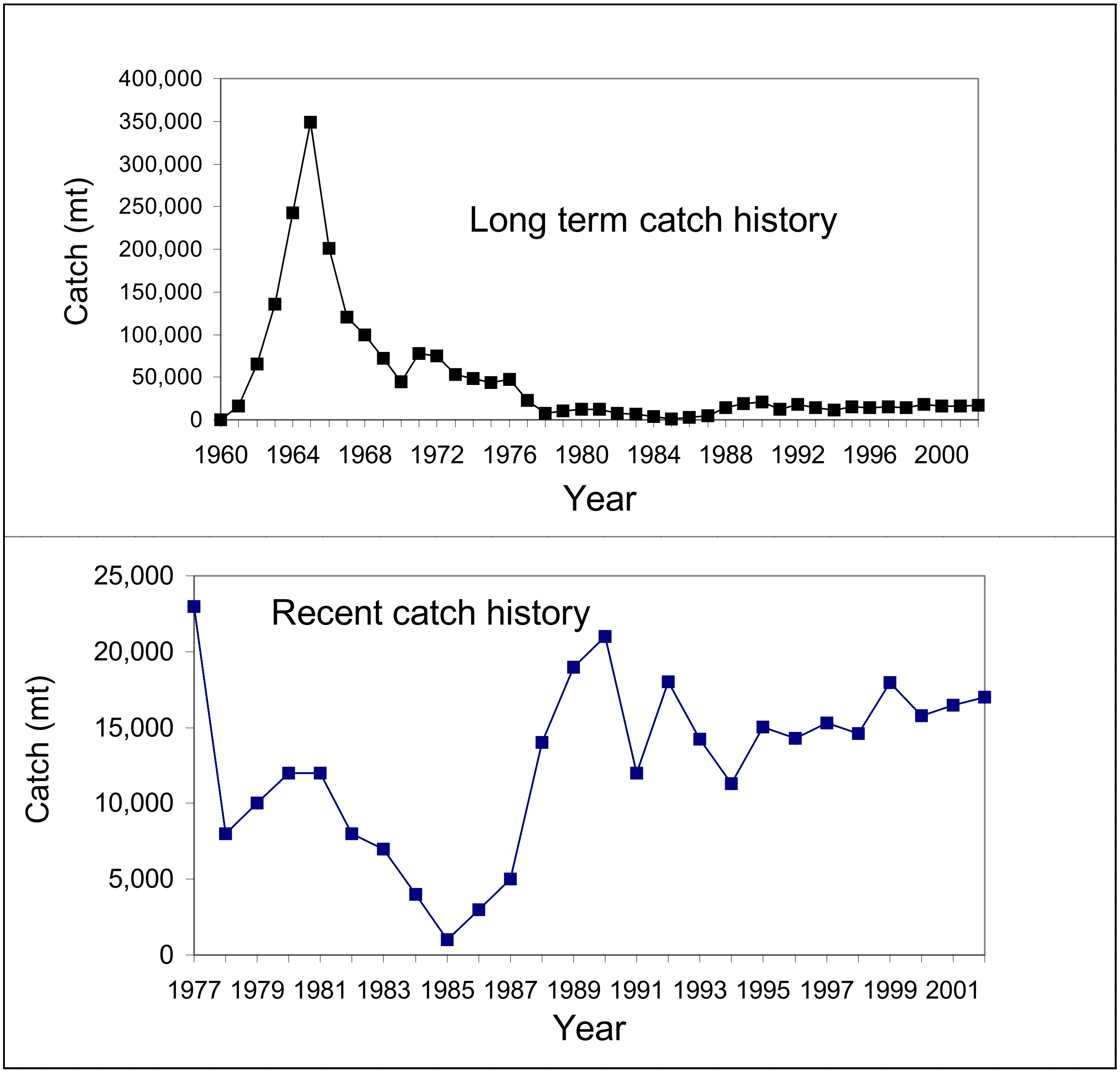


Figure 6-1. All nation catch of Pacific ocean perch and slope rockfish in the Gulf of Alaska as of October 5, 2002.

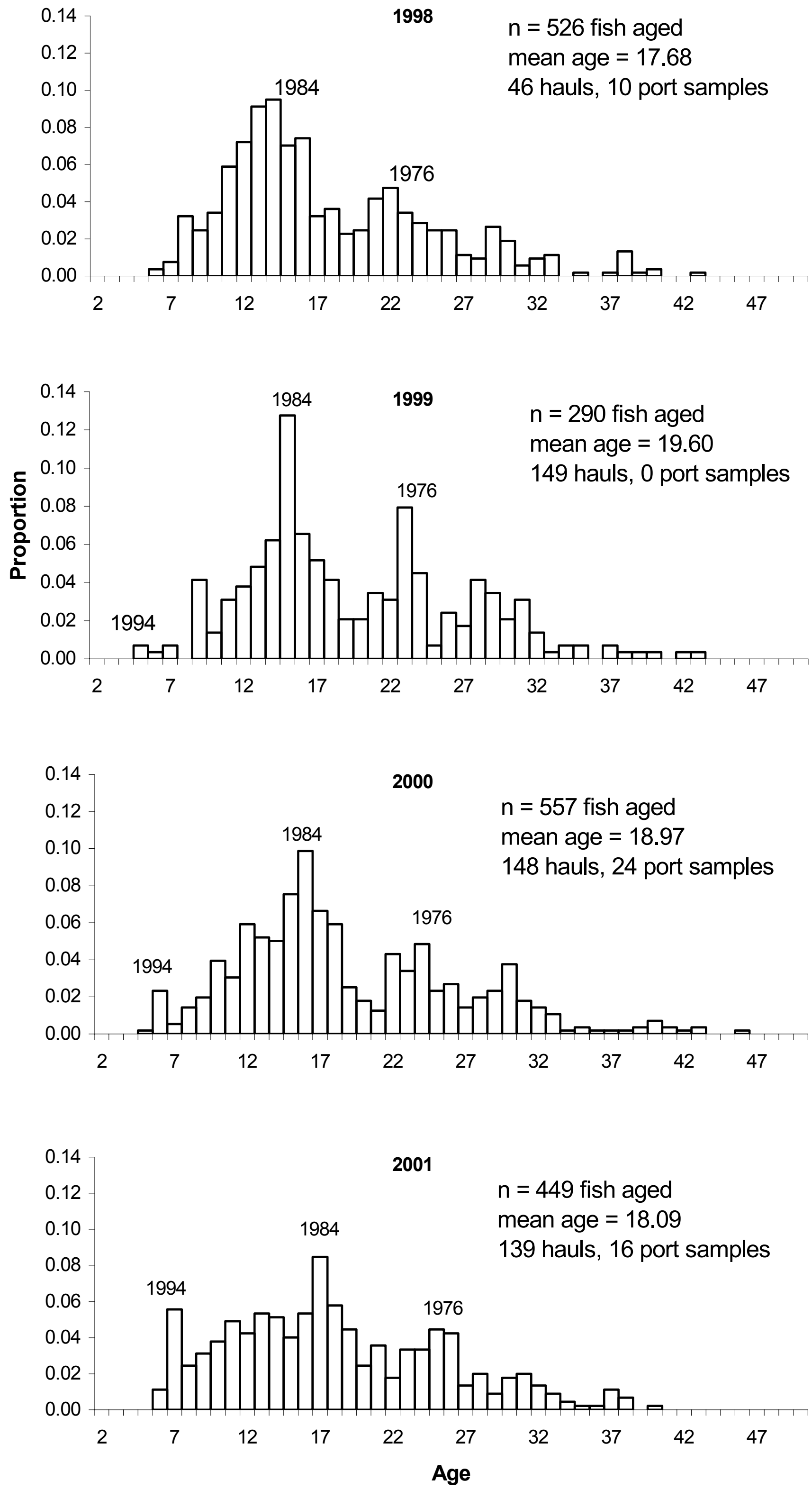
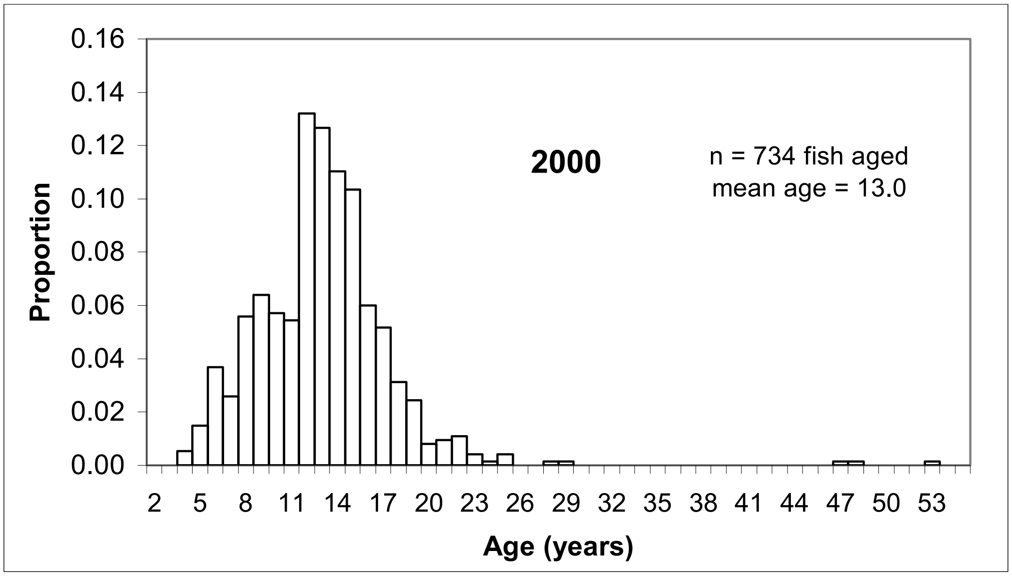


Figure 6-2. Age composition of northern rockfish in the Gulf of Alaska based on 1998 through 2001 fishery data.



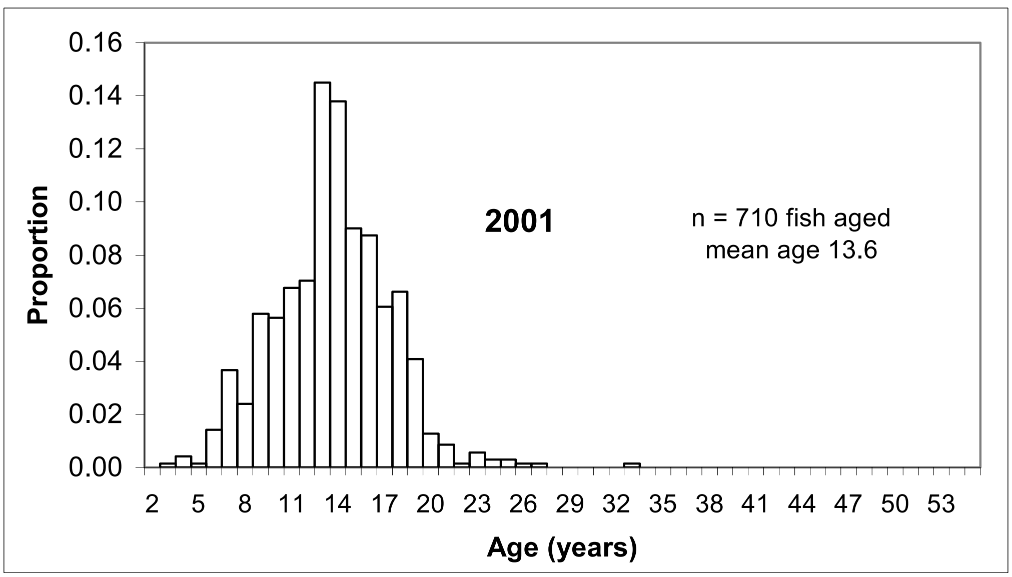


Figure 6-3. Fishery age composition of Pacific ocean perch in the Gulf of Alaska based on 2000 and 2001 data.

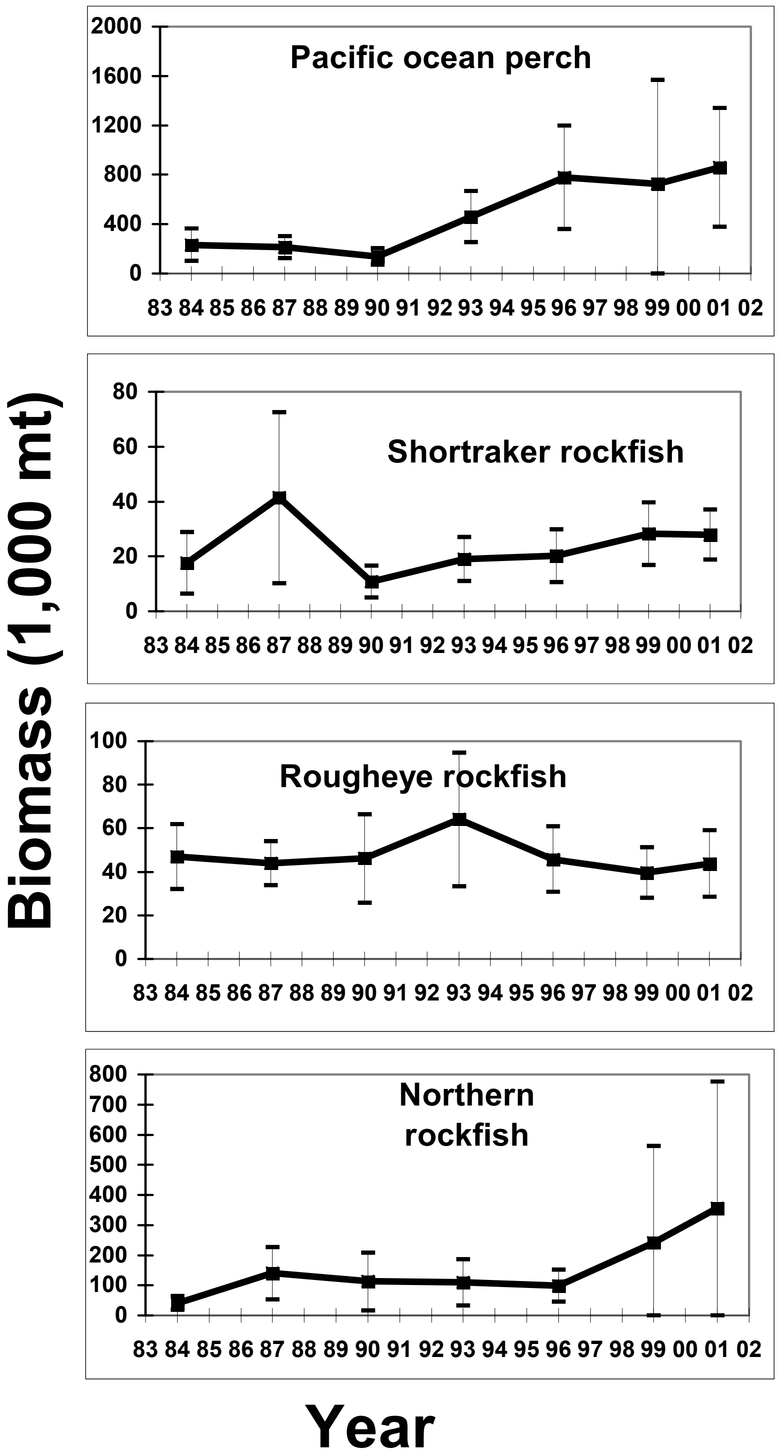


Figure 6-4. Estimated biomass of Pacific ocean perch, shortraker rockfish, rougheye rockfish, and northern rockfish in the Gulf of Alaska, based on results of the 1984, 1987, 1990, 1993, 1996, 1999, and 2001 trawl surveys. The vertical bars show 95% confidence limits associated with each estimate.

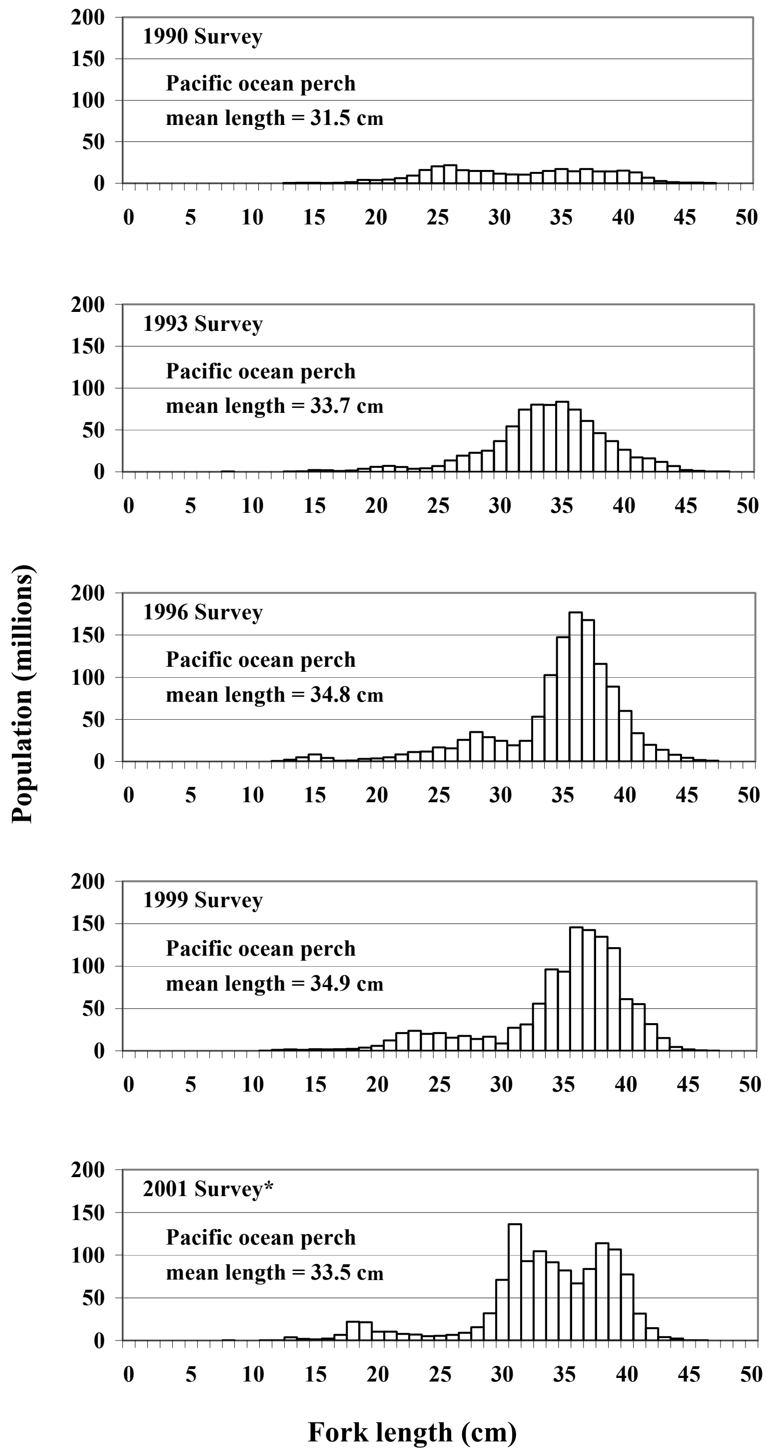


Figure 6-5. Length frequency distribution of the estimated population of Pacific ocean perch in the Gulf of Alaska, based on the 1990, 1993, 1996, 1999, and 2001 trawl surveys. *2001 survey did not sample the eastern Gulf of Alaska.

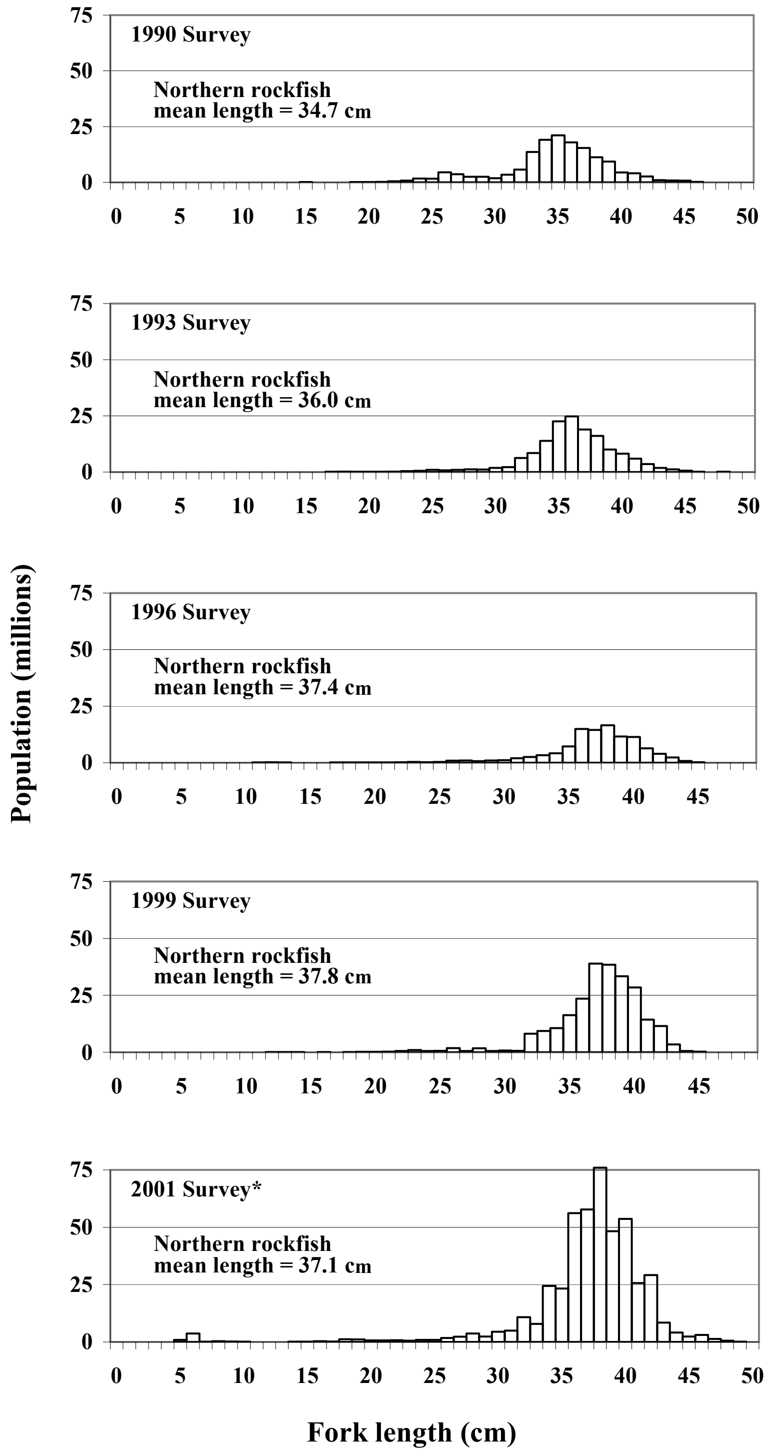


Figure 6-6. Length frequency distribution of the estimated population of northern rockfish in the Gulf of Alaska, based on the 1990, 1993, 1996, 1999, and 2001 trawl surveys. *2001 survey did not sample the eastern Gulf of Alaska.

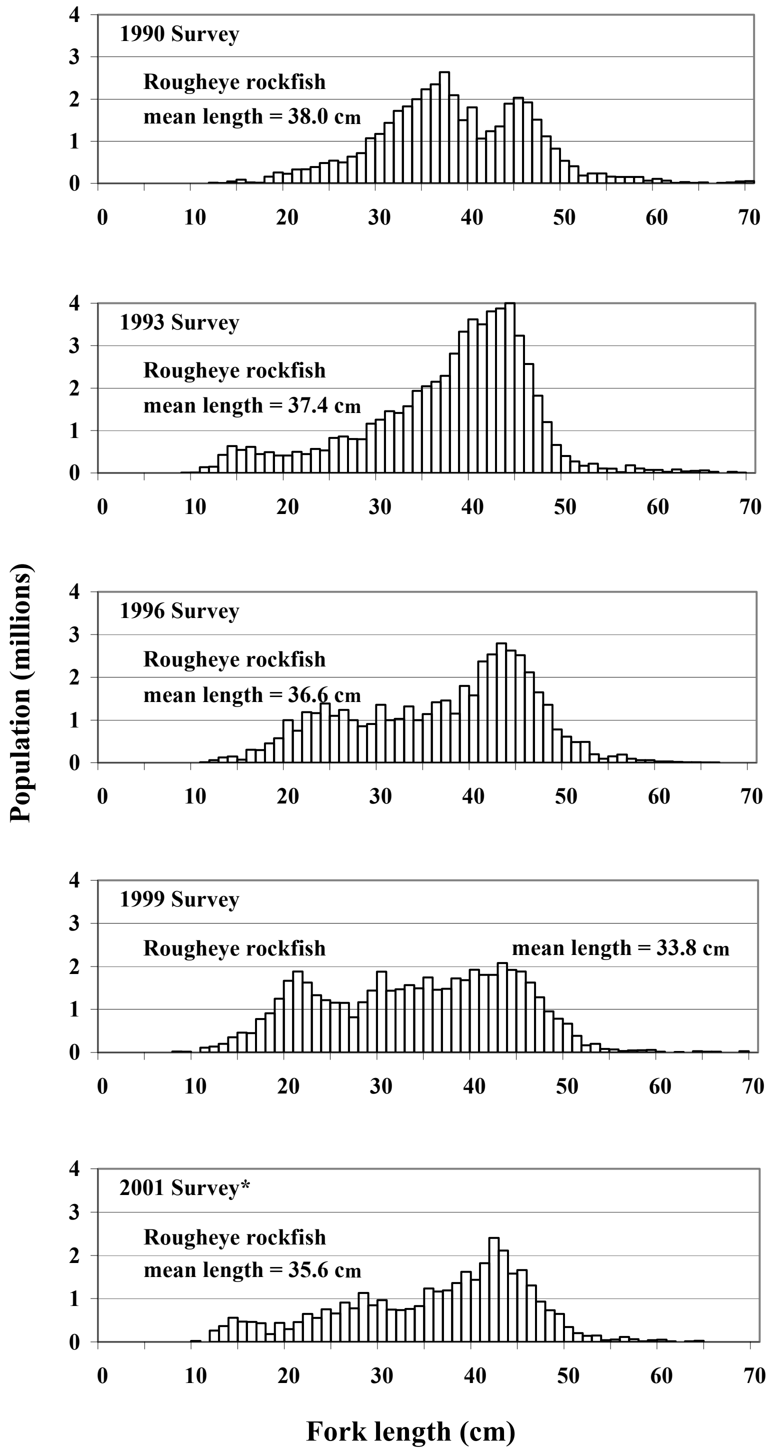


Figure 6-7. Length frequency distribution of the estimated population of rougheye rockfish in the Gulf of Alaska, based on the 1990, 1993, 1996, 1999, and 2001 trawl surveys. *2001 survey did not sample the eastern Gulf of Alaska.

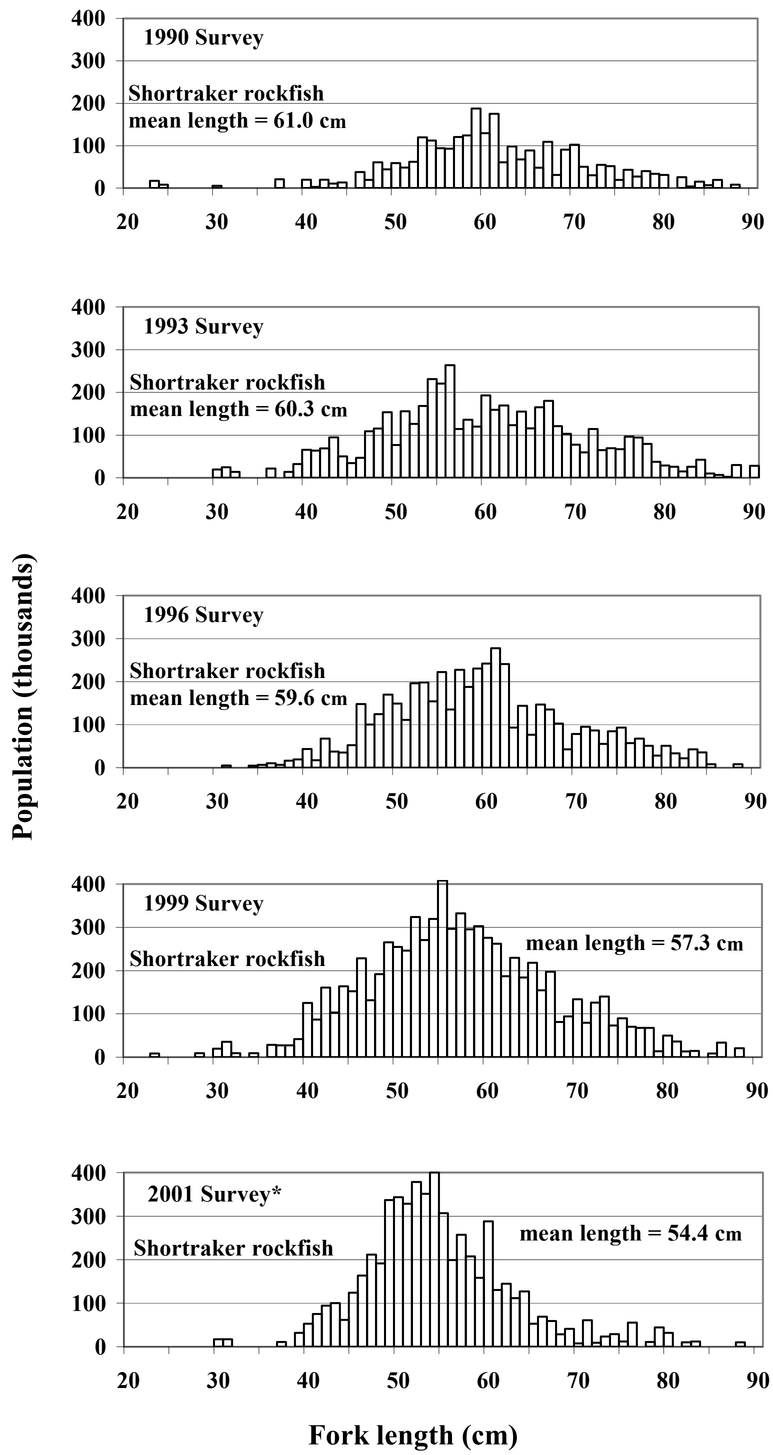


Figure 6-8. Length frequency distribution of the estimated population of shortraker rockfish in the Gulf of Alaska, based on the 1990, 1993, 1996, 1999, and 2001 trawl surveys. *2001 survey did not sample the eastern Gulf of Alaska.

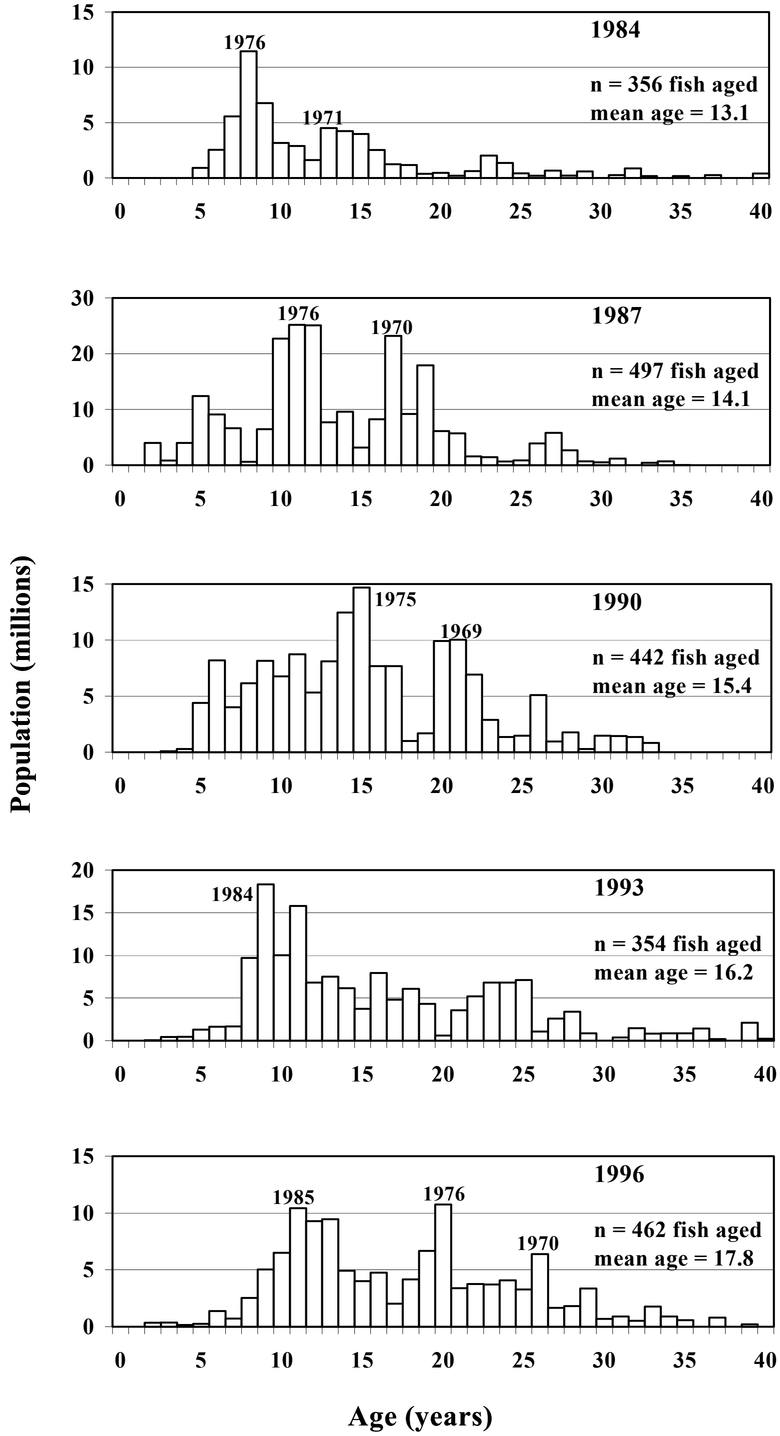
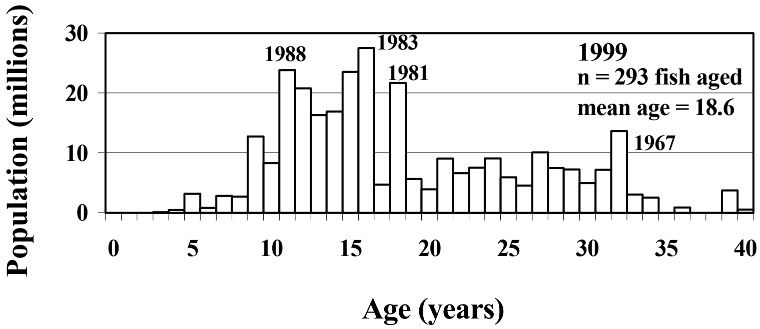


Figure 6-9. Age composition of the estimated population of northern rockfish in the Gulf of Alaska, based on the 1984, 1987, 1990, 1993, 1996, and 1999 triennial trawl surveys. The numbers next to prominent bars identify year classes that may be strong. (Figure is continued on next page.)

Figure 6-9.--(continued).



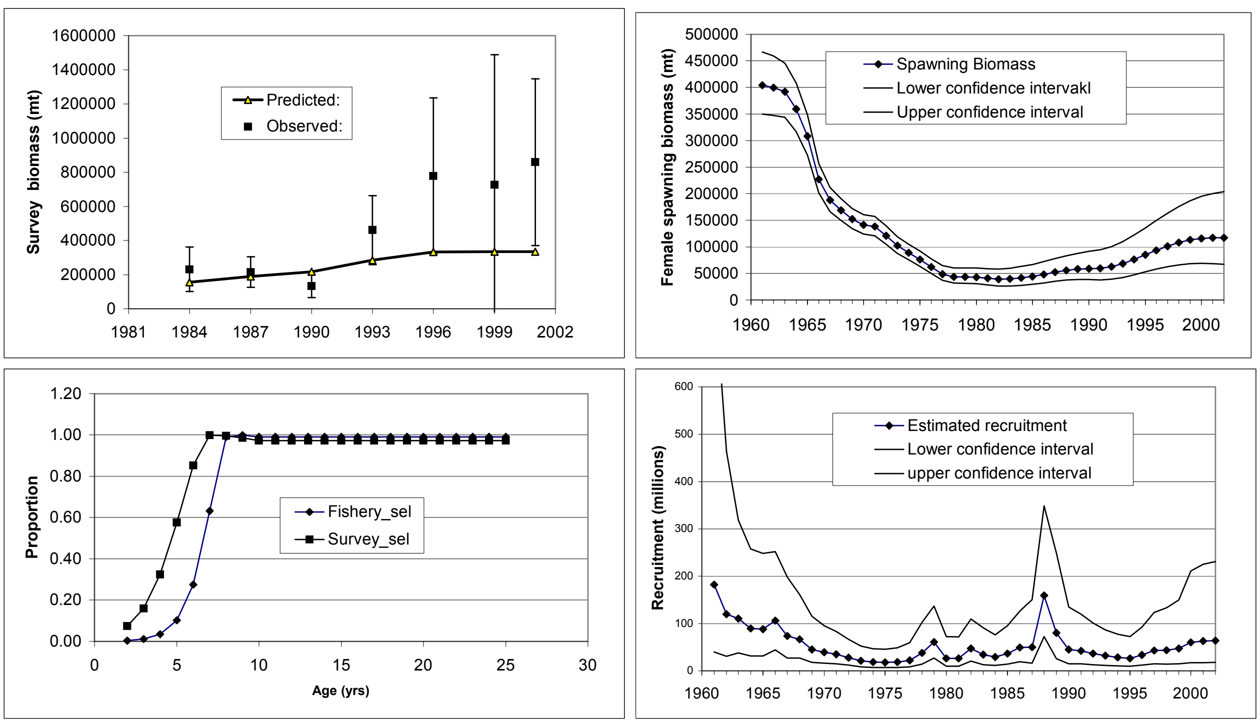


Figure 6-10. Predicted and observed survey biomass with 95% confidence intervals, estimated trend in spawning biomass, fishery and survey selectivity, and recruitment at age-2 for Pacific ocean perch in the Gulf of Alaska for the base model.

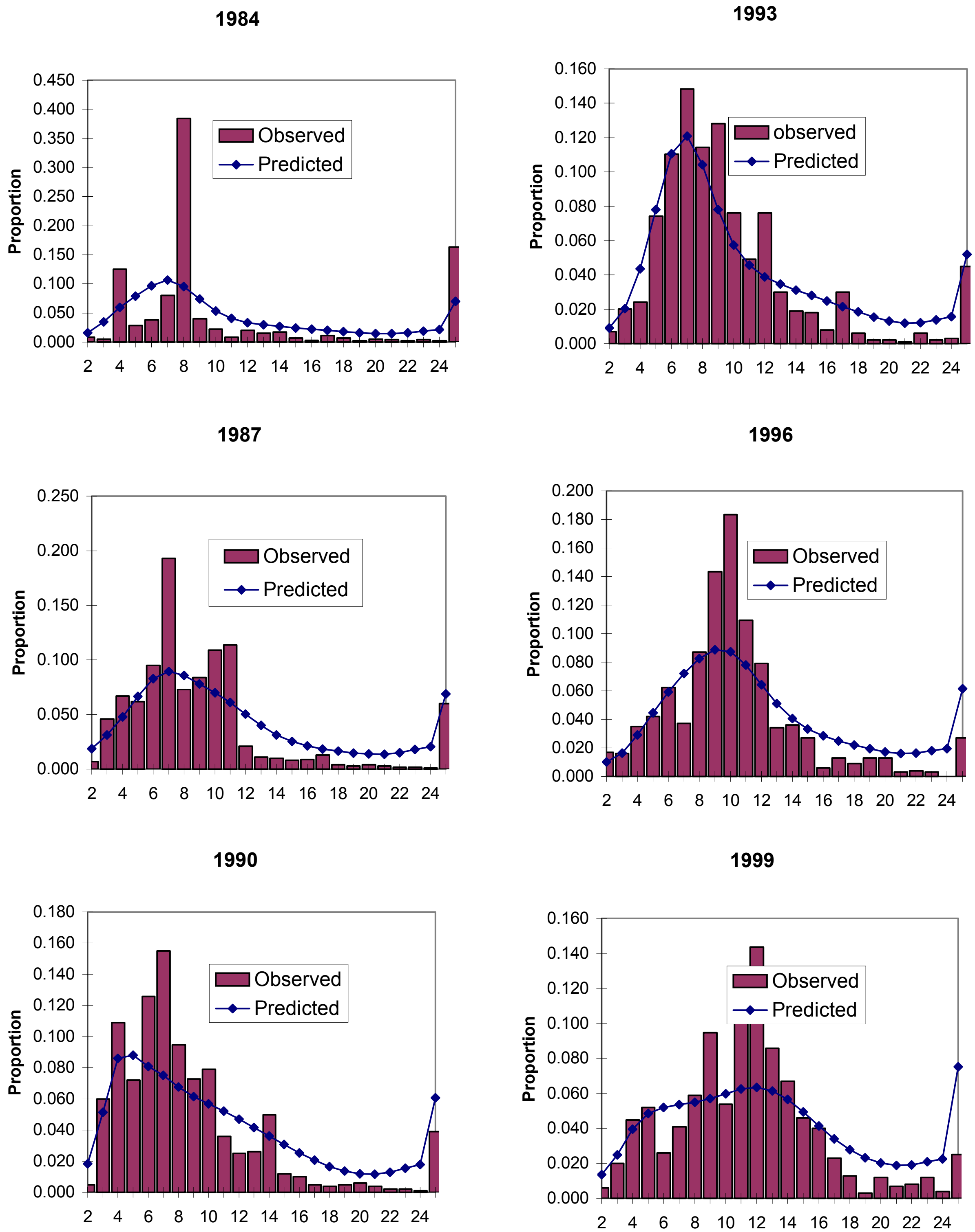


Figure 6-11. Observed and predicted survey age composition for Pacific ocean perch in the Gulf of Alaska based on the base model.

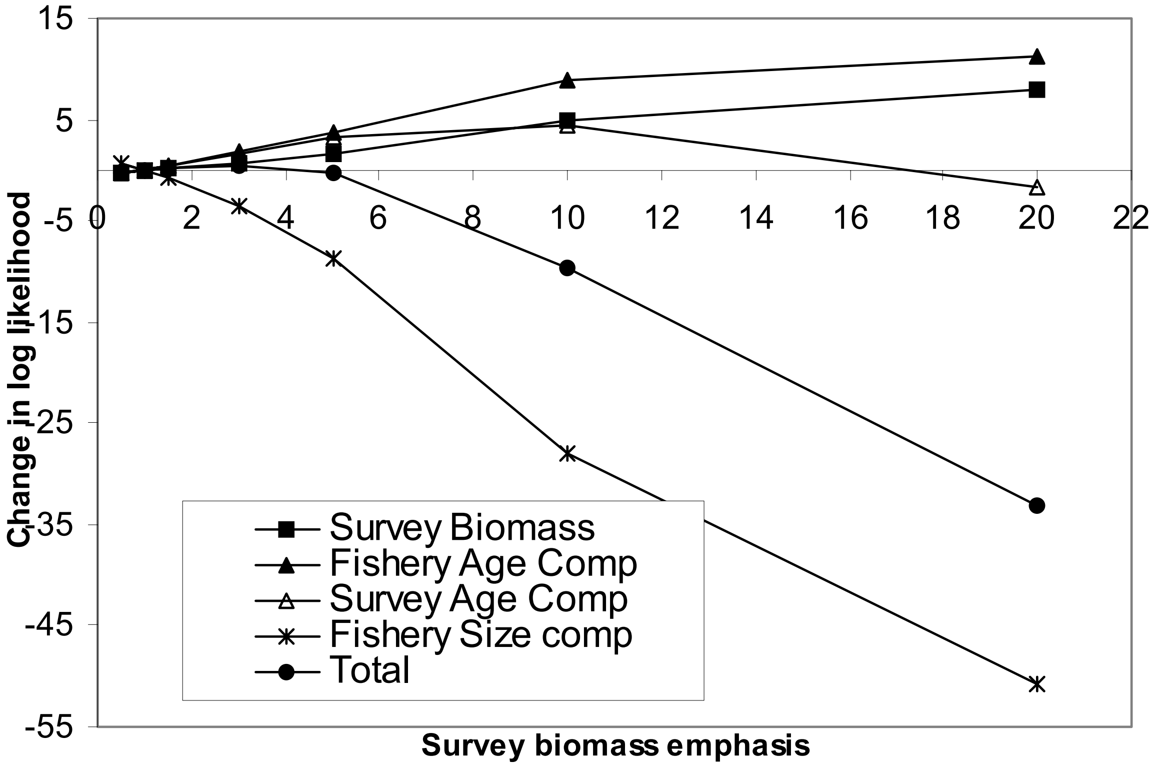


Figure 6-12. Relationship between the change in log likelihood values and emphasis on survey biomass for Pacific ocean perch in the Gulf of Alaska. A positive change indicates an improved fit to a particular data component.

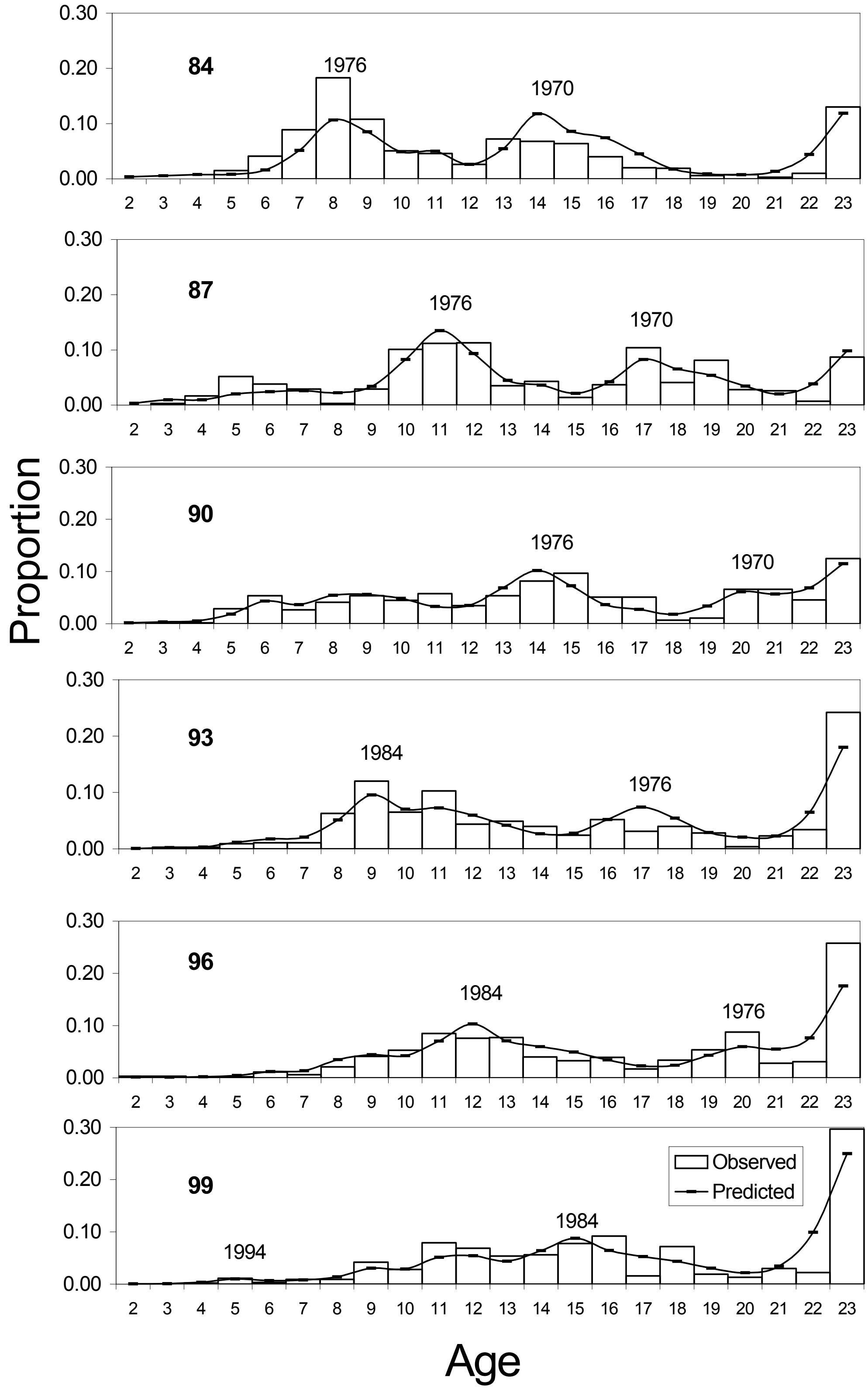


Figure 6 – 13a . Observed and predicted triennial survey age composition for northern rockfish in the Gulf of Alaska based on the age structured model.

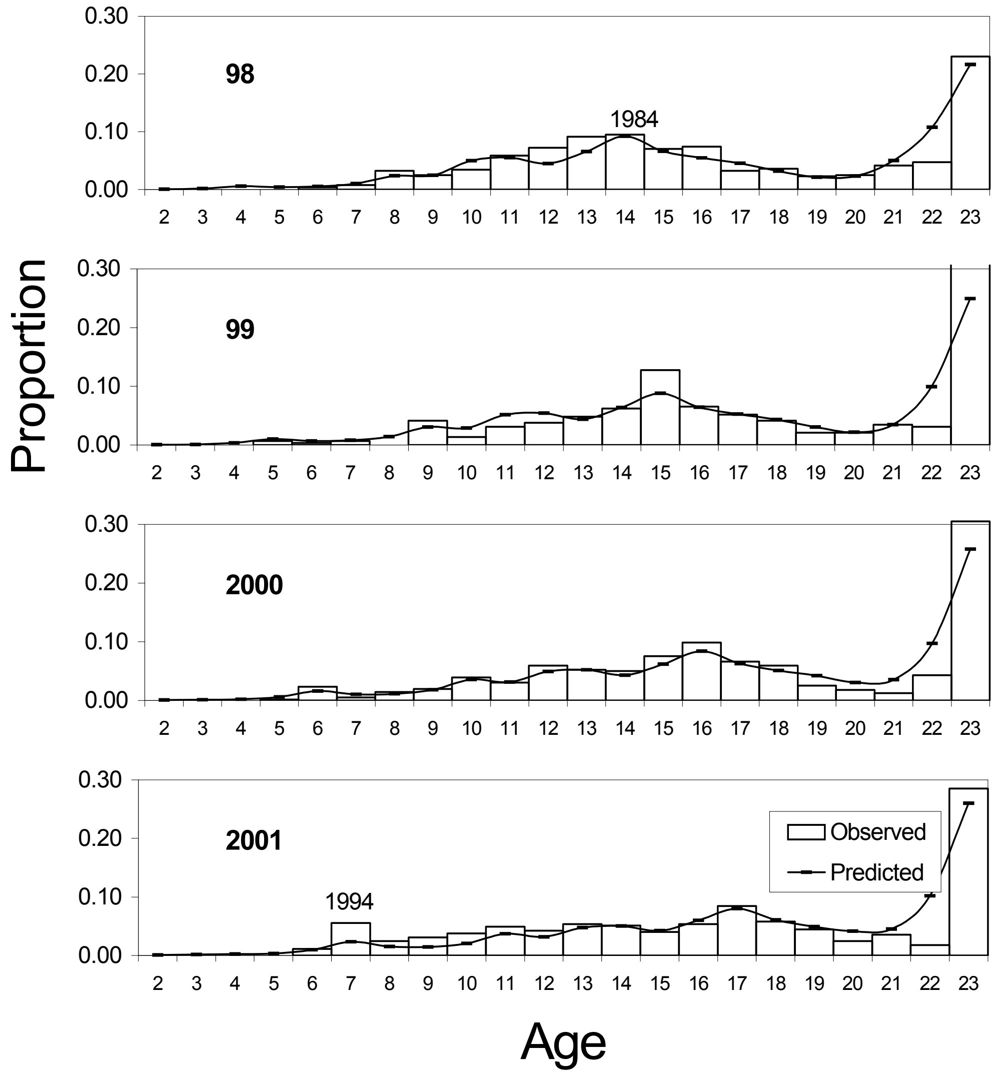


Figure 6 – 13b . Observed and predicted triennial fishery age composition for northern rockfish in the Gulf of Alaska based on the age structured model.

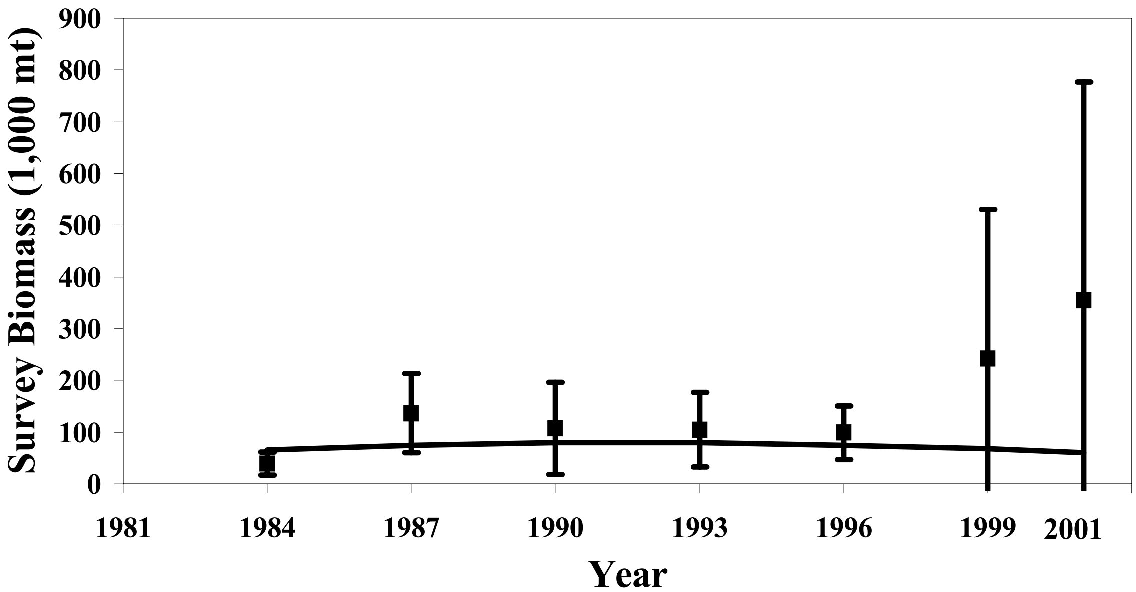


Figure 6-14. Observed and predicted survey biomass for northern rockfish in the Gulf of Alaska based on an age structured model. Ninety-five percent confidence limit is shown for each observed biomass estimate.

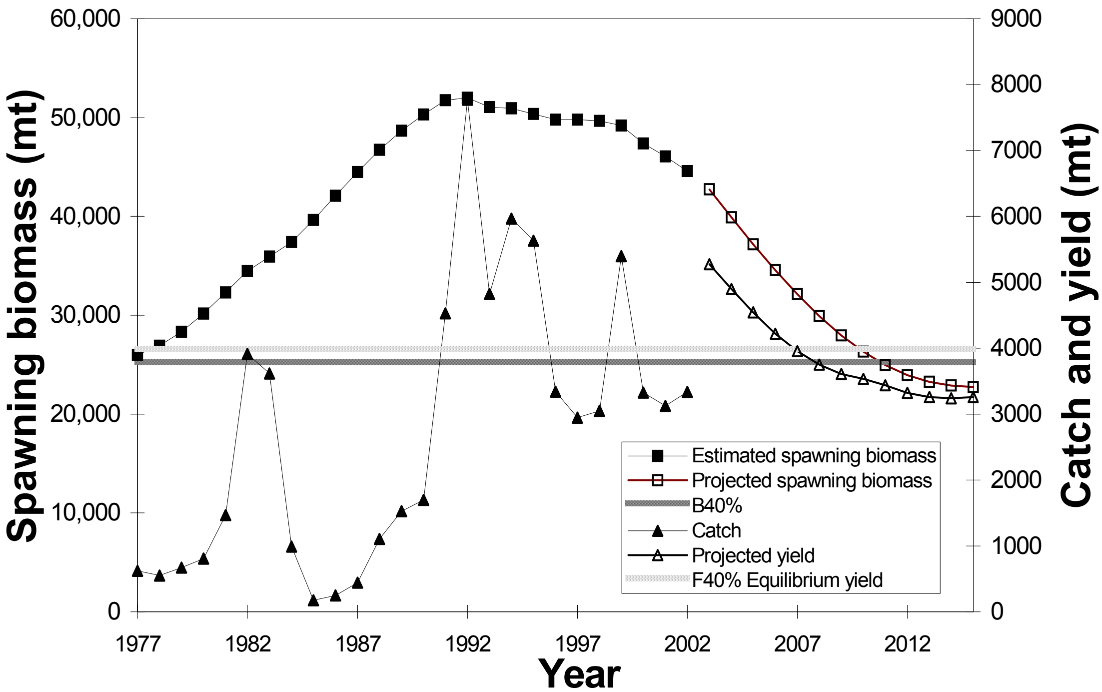


Figure 6-15. Recent trend and long-term projection of spawning biomass and yield of northern rockfish in the Gulf of Alaska based on tier 3 computations. At average recruitment (based on 1977-1994 year classes) the spawning biomass is projected to fall below B40% in 2008 and the catch is projected to fall below F40% equilibrium yield in 2010.

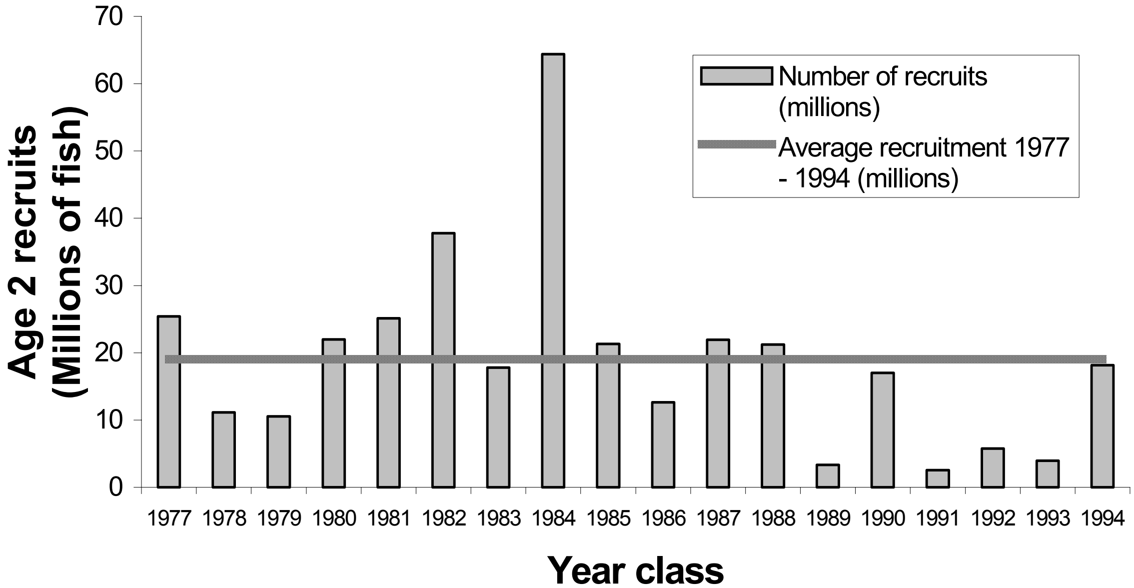


Figure 6-16. Number of recruits and average recruitment for year classes 1977 through 1994 from the age structured model for Gulf of Alaska northern rockfish.

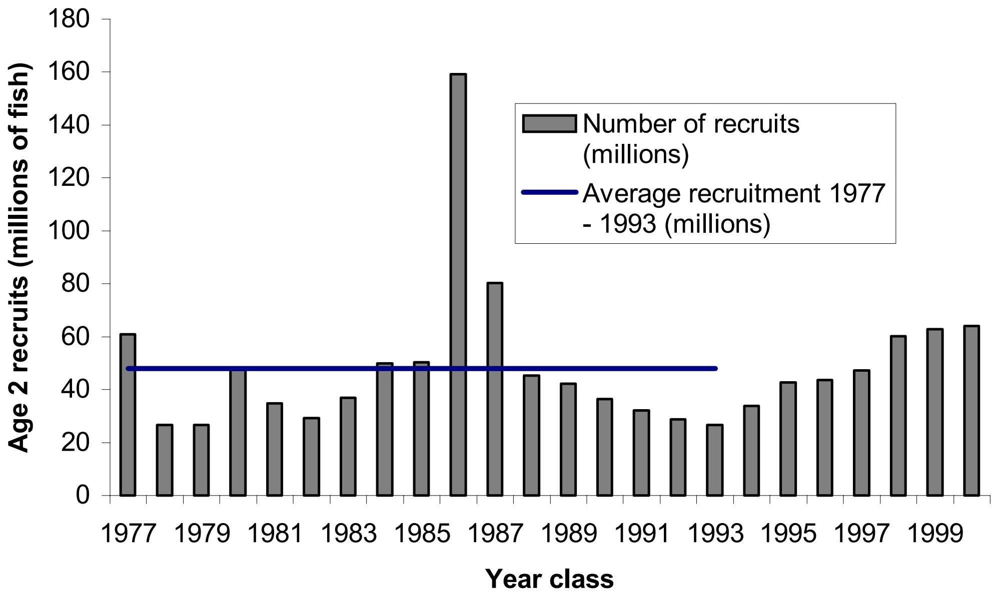


Figure 6-17. Number of recruits for year classes 1977 through 2002 and average recruitment for year classes 1977 through 1993 from the age structured model for Gulf of Alaska Pacific ocean perch.

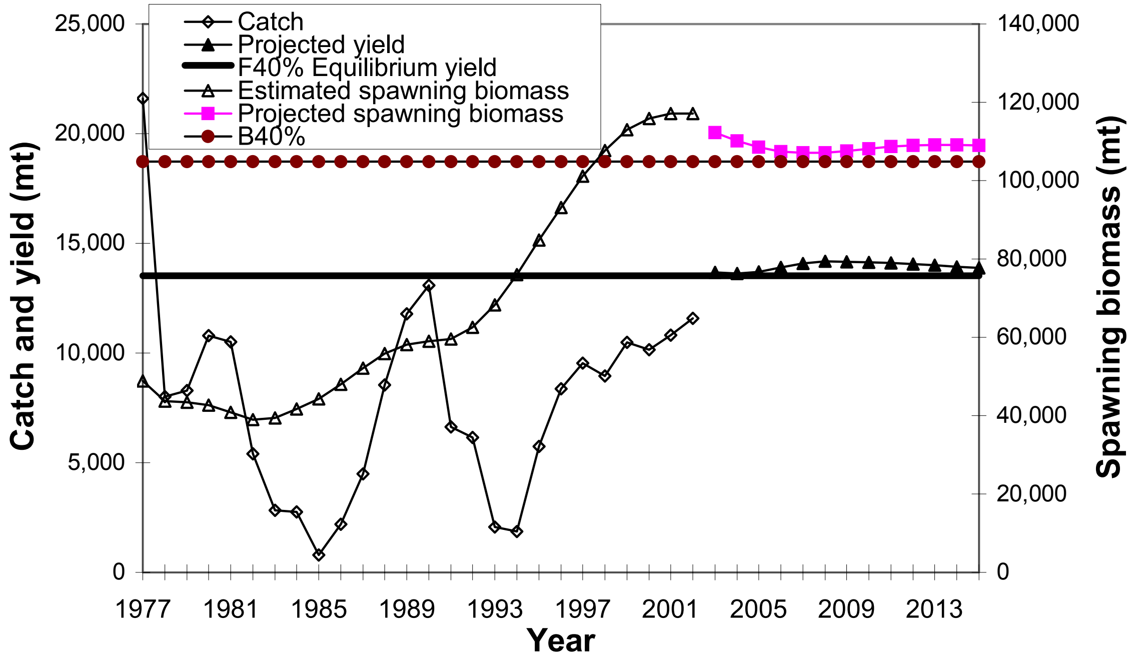


Figure 6-18. Recent trend and short-term projection of spawning biomass, catch, and yield for Pacific ocean perch in the Gulf of Alaska.

Appendix 6-1

Exploration of uncertainty in the Gulf of Alaska Pacific ocean perch assessment model

by
Dana Hanselman
November 2002

Even though an age-structured model estimates a large number of parameters, some parameters have a large influence on the model outputs. Survey catchability, *q*, and natural mortality, *M*, are two parameters that can have a large effect on the resulting *ABC* from the model. Previously, *q* has been constrained to be near 1 with a prior penalty, assuming that the trawl survey is catching all of the fish in the area swept and no more. *M* was assigned a "known" value of 0.05. Exploration of these parameters was performed by loosening the constraint on *q* and estimating *M*. Markov Chain Monte Carlo (MCMC) simulations were used to obtain estimates of the posterior distributions of important parameters in the model and compared to the maximum likelihood (ML) output of the model.

M

Estimating *M* tended to have a substantial effect on the model outputs for B_{40} and for ABC. In all scenarios, the model estimated lower values of *M* than the fixed value normally used. When *M* was allowed to vary with no prior penalties, it converged to ~0.025. If a prior penalty is added to constrain it to 0.05, the value ranges from 0.025 to 0.05. The ABCs that resulted when *M* was estimated were much lower than the base model estimate with *M*=0.05. The MCMC posterior distribution of *M* with no prior penalties was quite wide (Figure 1). The joint posterior distribution of *M* and *q* (Figure 2) was very interesting showing a bimodal posterior. There is a local maximum in the probability density at *M*=0.05 and *q*=1.5 and an absolute maximum at *M*=0.025 and *q*=2.25. This could indicate that by constraining the natural mortality to 0.05 we may be confining the model to a less likely mode of the posterior distribution.

q

Loosening the constraints on *q* when natural mortality was fixed had small effects on the model. The estimate of *q* ranged from 1.0 to 1.15 depending on the variance assigned to the prior penalty. The MCMC estimates of the posterior distribution for *q* always contained the ML estimate of *q*, but it often was well below the mode of the distribution. In the base model, the mode of the posterior for *q* differs greatly from the MLE estimate of *q*=1.10 (Figure 3). When *q* and *M* were estimated together, the changes in the model were more substantial. As *M* decreased, *q* estimates ranged from 1.6-1.8. The resulting ABCs and biomass estimates decreased depending on how much the two parameters were allowed to vary.

ABC

The posterior distribution estimates of *ABC* for the base model appear to be quite uncertain (Figure 4). The ML estimate of *ABC* is contained in the distribution but falls on the far right tail. The distribution is skewed with a mode at a much lower value than the ML estimate. In a model run where *q* was fixed at 1 and *M* was estimated, the resultant posterior distribution for *ABC* was less skewed and closer to the ML estimate (which was lower).

Implications

These preliminary results indicate the need for further research into identifying and quantifying the sources of uncertainty in the model. The result of most changes to the way parameters are estimated and weighted result in lower estimates for *ABC*, with the main exception being a higher weight on survey biomass. This does not imply that the model is overestimating biomass, just that caution is necessary while uncertainties are quantified. Some of the data seem contradictory because different weightings on different data components can result in large changes in model outputs. For next year's assessment a formal Bayesian framework and decision analysis would be useful to quantify the effects of our assumptions about parameters and data.

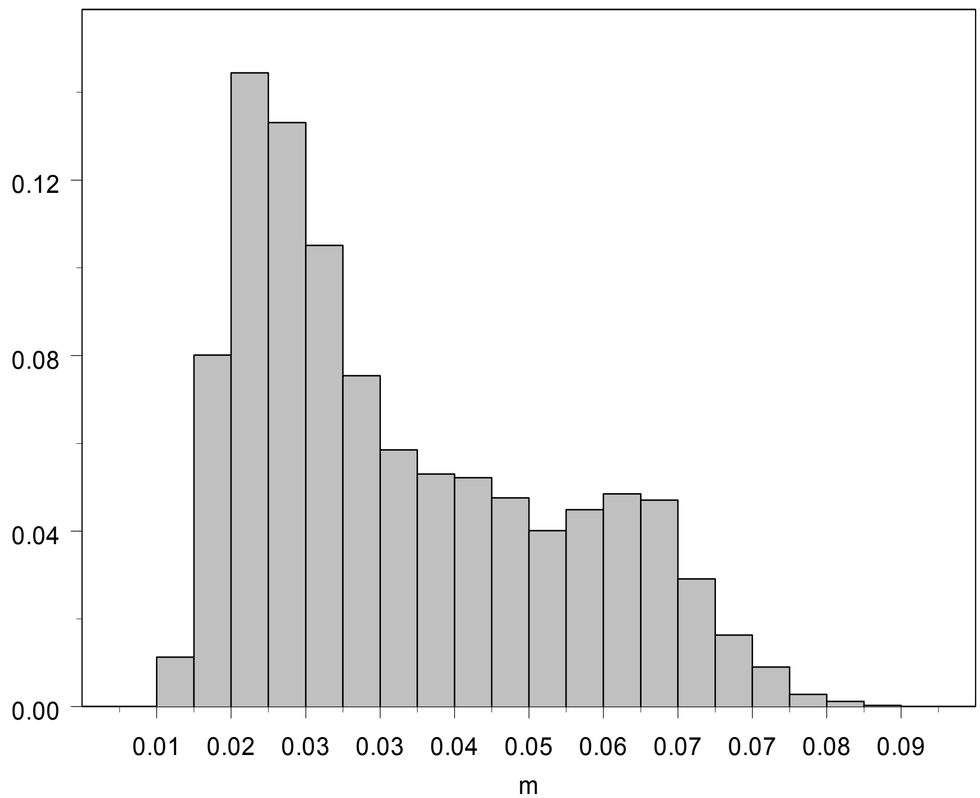


Figure 1. Frequencies from a sample of 10,000 parameter values from a Markov Chain (length 1,000,000) estimating the posterior distribution of *M* for a model estimating *M* and *q* with no constraints.

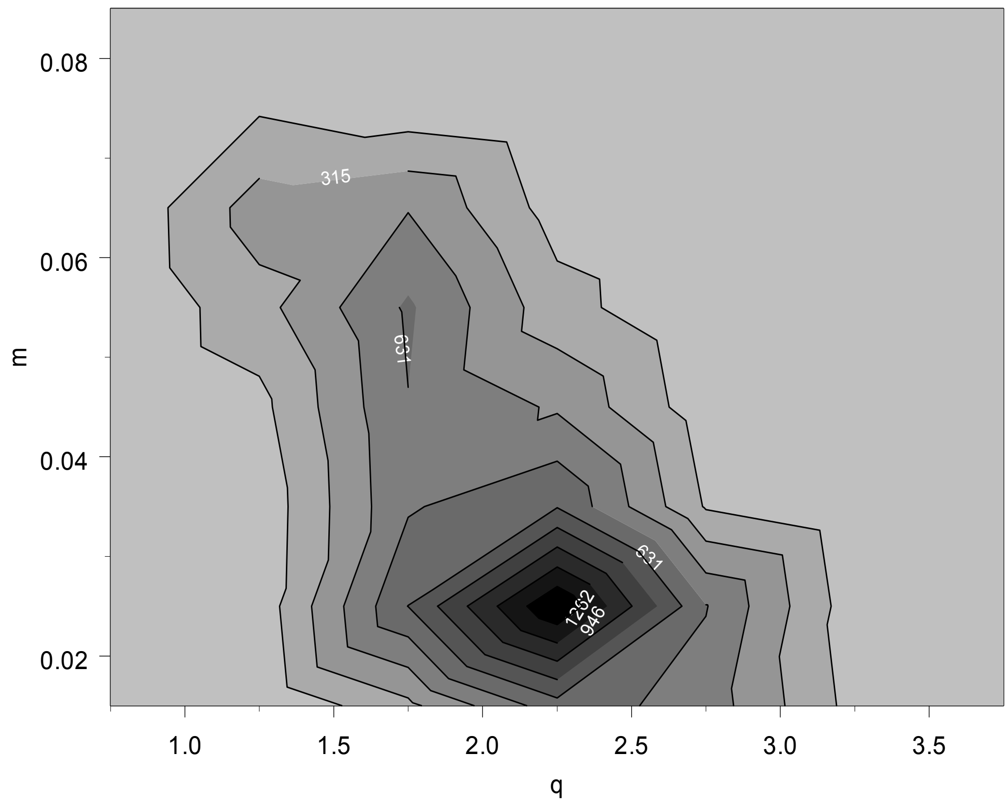


Figure 2. Estimate of the joint marginal posterior distribution for *M* and *q*. Sample of 10,000 parameter estimates from a Markov Chain (length 1,000,000) from a model that estimates *q* and *M* with no constraints.

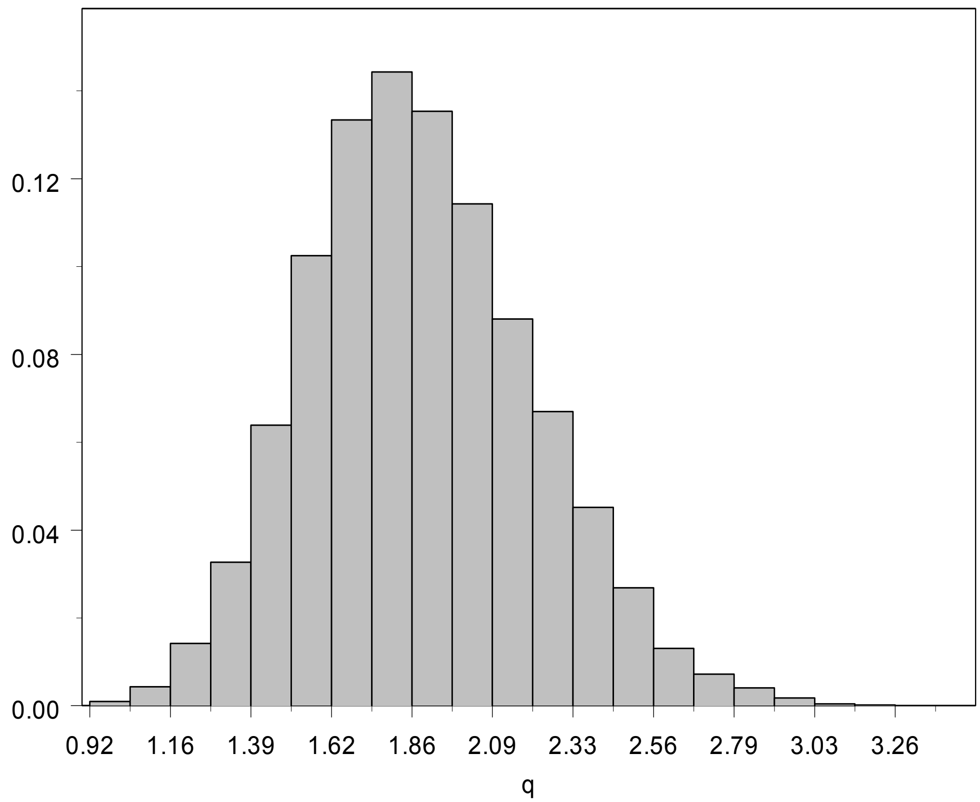


Figure 3. Frequencies from a sample of 10,000 parameter values from a Markov Chain (length 1,000,000) estimating the posterior distribution of *q* for the base model.

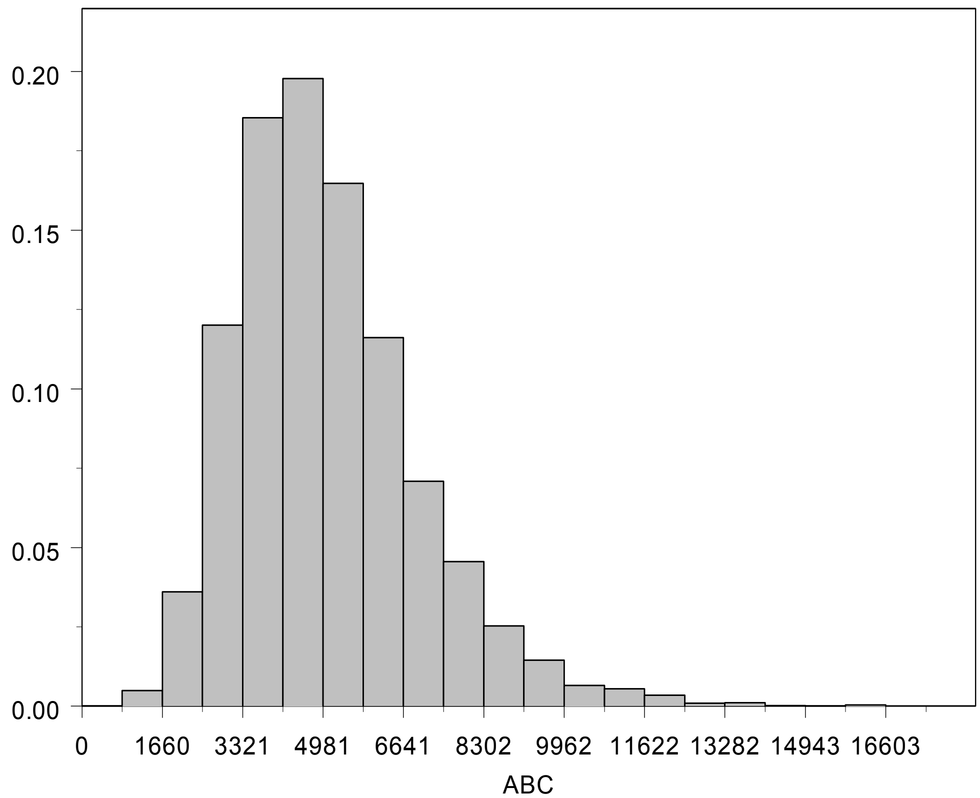


Figure 4. Frequencies from a sample of 10,000 samples from a Markov Chain (length 1,000,000) to estimate of the posterior for *ABC* in the base model.